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LESSONS AND EXPERIMENTS
ON
SCIENTIFIC HYGIENE AND TEMPERANCE
FOR
ELEMENTARY SCHOOL CHILDREN

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LESSONS AND EXPERIMENTS
ON
SCIENTIFIC HYGIENE AND TEMPERANCE
FOR
ELEMENTARY SCHOOL CHILDREN

3.1915.

BY

HELEN COOMBER
BSc. Lond.

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INTRODUCTION

In offering these Notes of Lessons for Children to School Teachers and School Managers, a few words in explanation of their origin and their scope may be useful.

They are the outcome of a long-continued effort, begun in 1903 by over 15,000 of the Medical Profession, to get the teaching of hygiene and temperance introduced into the time-tables of all the Elementary Schools.

Deputations of the Profession, including, among others, Sir Thomas Barlow, Sir Lauder Brunton, Mr. M'Adam Eccles, Sir Alfred Pearce Gould, Sir Victor Horsley, Dr. Mary Sturge, and Professor Sims Woodhead, waited on successive Presidents of the Board of Education to urge upon them the great national importance of giving such teaching in the Schools, and they placed in the hands of the Board of Education a scheme of lessons which they had drawn up to facilitate the object they had in view.

For several years these deputations were entirely unsuccessful. In 1909, however, under the Presidentship of Mr. Runciman, the Government Syllabus of "Lessons on Temperance" was issued, based upon the medical scheme, and a great step towards the uplifting of the country was thus made, for though the Syllabus is of necessity highly condensed and unpretentious, it gives both direct knowledge and warnings which are quite essential to the children for the reasonable conduct of their lives.

But before the Syllabus could really reach the children some road-making had to be done.

The School time-tables are overcrowded, the teachers over-tired, and yet the Syllabus to convince the reason of the children needs extension and subdivision.

Further, many non-abstaining teachers are not interested in the subject, and do not desire to teach it because they have not grasped the unique combination of the educational with the practical, which it offers.

In order, therefore, to overcome these difficulties it was decided, after consulting the views of as many head-teachers as possible, to draw up a series of experimental lessons in physiological hygiene and temperance for the threefold purpose of giving the children a good rule of life, a good reason for the rule, and a scientific training, which by stimulating observation and reasoning, and forming the scientific habit of seeking out causes instead of accepting effects, should really develop the brains and the intelligence of the children. Thus they should pass out into the world more alert and alive to cope with its problems, and to take in what new ideas and further teaching the State or their employers might afterwards afford them.

Lord Haldane has recently pointed out that science gives a mental training which can never be obtained by other means, and which ought to form part of every education; and this particular science of physiological hygiene and temperance would not only benefit every child in the schools, but the whole community also, through the reduction which it would bring about in crime, poverty, and sickness, and the costly machinery of police, magistrates, and hospitals necessary to deal with these evils.

It is therefore earnestly to be hoped that School Authorities will at last do justice to the obvious importance of this subject, and give it a front rank in the curriculum, even if, in order to do so, they have to sacrifice other teaching which has hitherto been given the precedence in popular estimation.

In view of the foregoing considerations, therefore, the following Course of Lessons has been drawn up with special reference to the Elementary Schools.

The Author, Miss Helen Coomber, has endeavoured to use only the plainest and most colloquial language possible to suit the extremely narrow vocabulary of the children, the apparatus is the cheapest and simplest that could be devised, and though the lessons are given in minute detail, it is obviously open to any teacher to modify them at will to suit the exigencies of each particular school.

Those who are acquainted with the Board of Education Syllabus, around which these lessons are planned, may feel some surprise that the " civic " or " moral " side of the teaching has not been directly included. The reason is simply that, though this is the most important outcome of the whole subject, teachers need no specialised help in presenting it, and can easily deal with this part of the question after the manner which they may individually find expedient.

In conclusion, it should be said that much helpful criticism and suggestions have been given by practical teachers and physiological experts, and that all the scientific statements have been submitted to and approved by Sir Victor Horsley, who has made a special study of the question.

EXPLANATORY NOTE

The following lessons are based on the matter contained in the Board of Education Syllabus "Lessons on Temperance."

They are an attempt to make the teaching of the facts there outlined really educational, because based upon experiments, observations, and deductions made by the children themselves. The greater proportion of the lessons is concerned with the physical, chemical, and biological facts, a knowledge of which must be, to a reasonable being, the best foundation for belief in temperance; but knowledge of these same facts is also the groundwork for right thinking in all healthy living, and most of the hygiene now taught in the schools also needs a basis of simple experimental work if it is to be real to the children. With the surely coming extension of the compulsory school age there will be an increasing demand for such teaching, and it is hoped that these lessons may make it easier for the teachers to provide it.

In order to emphasise the point that the children are as far as possible to find out the facts for themselves, these Notes are largely in the form of question and answer, as a reminder that the lesson which contains the minimum amount of statement on the part of the teacher is the best. So much of the subject cannot be taught experimentally that it is fatally easy merely to pour out information upon the children. It is not to be supposed that the children are expected to return at once the answer given in the lesson to any one question, nor indeed that the lessons will follow this exact course. A whole series of questions and answers may often be needed to lead up to any of those in the Notes, in which only the main trend of the argument can be indicated.

The work was planned for children of eleven to fourteen years of age, and forty-minute lessons are best suited for this type of experimental work; but there is so much variation in the schools as to time given, size of classes, previous training of children in experiment and self-expression, that it seems best to divide the subject-matter up into sections and not into separate lessons, leaving this further subdivision to the individual teacher. Some of the earlier sections might well be divided into three or four lessons lasting perhaps for shorter periods than forty minutes. The end of a lesson or of such a group of subdivided lessons must be arranged to fall at the end of a section, as often some time is required to elapse between the setting up of an experiment in the one section and its completion in the next, and also with each section a new " Aim " becomes the basis of the work.

Parts of sections dealing with protoplasm and molecular structure and certain other points have been included in brackets *( )*, as being more difficult conceptions suitable for older children only, and can be omitted at the discretion of the teacher. Questions are sometimes asked by the children which might necessitate some such treatment of the subject, and such words as molecule, protoplasm, etc., are now so common in our newspapers that it does seem desirable to give the children some idea, though necessarily an imperfect one, of their significance, and when, as we all hope, the school age is extended, the older children will require more of such education.

Other portions of the subject-matter are included in brackets ( ) to indicate that they are for the information of the teacher only, *e.g.* names of chemicals or names of parts of the body not needed by the children.

A list of books which have proved most useful to myself and other teachers is herewith added, and also a list of the apparatus, etc., required. This latter ordinarily costs about £1 : 15s., and would probably cost less when obtained from the County or Borough Educational authority.

HELEN COOMBER.

BOOKS

(All for Teacher, none for the children to use.)

Chemistry. *Introduction to Chemistry and Physics.* Perkin and Lean. Vol. II. 2s. Or any Introduction to Study of Chemistry.

Physiology. *Physiology for Beginners.* Foster and Shore. 2s. 6d.

Hygiene. *Lessons in Practical Hygiene.* Alice Ravenhill. 7s. 6d. Most comprehensive and useful, but very few illustrations or diagrams.

Anatomy, Physiology, and Hygiene. *The Human Body.* H. V. Martin. (In American Science Series. Briefer course.) 6s. 6d. Has many illustrations.

The Body at Work. 50 cents each. Books III. and IV., in the Gulick Hygiene Series, are really intended as "Readers" for the children, but are only mentioned here as being very suggestive for the teacher, as containing extra and interesting information, as being very cheap.

Alcohol and the Human Body. Horsley and Sturge. 1s. As this has been the main text-book used in preparing these lessons, and contains all the physiological information required for them, it is almost indispensable.

REQUIREMENTS FOR COURSE

FOR EVERY CHILD.

A notebook, preferably with blank pages for sketches. Squared paper for diagrams, red and blue coloured chalks.

PHYSICAL AND CHEMICAL APPARATUS.

Balance needed for two experiments only. (Small 2s. 6d. balance as used by doctors for dispensing purposes can be used.) Counterbalancing of magnesium against same magnesium oxidised. Section II.

File for glass tubing.

Iron tripod stand.

1 or 2 large spirit-lamps.

Bunsen burner (for Section II.) and tubing long enough to reach gas-burner.

Blow-pipe.

2 clips for closing rubber tubing.

1 yard rubber tubing, $\frac{1}{16}$ inch bore.

6 test-tube corks, unbored.

2 corks for 250 c.c. flask.

Cork borer, or 3 rubber corks with two holes already bored in each to fit flask and large test-tube.

Packet of filter papers about 4 inches diameter.

GLASS APPARATUS, ETC.

One 350 c.c. beaker.

One 250 c.c. flask.

Filter funnel.

Thistle funnel.

3 yards glass tubing $\frac{3}{16}$ inch bore, not too hard to just bend in spirit-lamp flame to make U-tubes for oxidising of food-stuffs with copper oxide.

10 inches soft glass tubing $\frac{3}{8}$ inch bore.
3 inches glass tubing $\frac{1}{8}$ inch bore.
1 dozen test-tubes.
1 large test-tube (with 2-holed rubber cork to fit).
2 evaporating dishes.
2 crucibles with lids.
Centigrade thermometer.
Animal parchment, 4-5 inch squares.

CHEMICALS. (Smallest quantity of each that can be bought—usually 1 oz. is more than will be needed for one set of lessons.)

Magnesium ribbon, 1 yard.
Iron filings.
Granulated zinc.
Carbon.
Marble—half a dozen small pieces.
Copper oxide.
Copper sulphate.
Manganese dioxide. Potassium chlorate (for making oxygen).
Iodine, tincture of.
Litmus (solid for dissolving) and litmus paper.
Fehling's solution (if possible). Obtain from chemist the two separate solutions, one colourless (alkaline potassium tartrate) and the other pale blue (copper sulphate), and only make up your Fehling just before the lesson, adding a little of the blue solution to an exactly equal amount of the colourless, and only making up as much as will be needed for the lesson. If kept mixed for more than a few months changes occur in the solution and the test may not come off.
Lime-water can be made by boiling up a handful of lime (calcium oxide) with distilled water for 15 minutes. Then allow to cool and filter off the liquid.
Distilled water.
Nitric acid (spirits of nitre).
Hydrochloric acid (spirits of salt).
Ammonia.
Benger's Liquor Pepticus (if second digestive experiment performed). Section XXVIII.

HOUSEHOLD THINGS USED.

2-lb. jam jars and potted meat jars.
Enamel or glass dish.
Medicine bottles.

Egg cup.
Scissors.
Candles.
Tapers.
Lamp wick.
Methylated spirit.
Cleaned photographic plates or glass squares.
Clinical thermometer.
Washing soda.
Saltpetre.
Sand.
Lard.
Suet.
Starch.
Flour, rice, tapioca.
Sugar, salt.
White of egg, lean meat, tea.
Rabbit's hind-legs.
Rabbit's brains.
2 or 3 sheep's hearts and lungs and windpipe.
$\frac{1}{4}$ pint fresh blood (sheep's or bullock's).
Frog or toad spawn, tadpoles.
1d. worth yeast.
Teacupfuls gin, stout, medicated wine.

SUMMARY OF SECTIONS

PAGE

SECTIONS I.–IV. Study of simplest processes of oxidation leads up to oxidation in the body, and is the easiest road to some conception of chemical change 1-14

SECTIONS V.–IX. Examples of slow combustion, *i.e.* oxidation without light or sensible heat leads to the idea that certain foods can also be oxidised in the body and produce the energy it requires 15-32

SECTION X. Heat a form of energy 33

SECTIONS XI.–XIII. Energy for muscular movement is supplied by oxidisable food-stuffs, but such movement is controlled by the protoplasm of the brain and nervous system; hence alcohol, although oxidisable, inhibits such movements . 40-52

SECTIONS XIV.–XV. How food-stuffs reach those parts of the body where they are needed, since some of them will not pass through the digestive-tube wall 53-58

SECTIONS XVI.–XXV. Oxidation as a source of energy in relation to cell protoplasm and its growth and body-building powers. Effect of alcohol on cell growth. The cell as a producer of ferments which can render the insoluble foods soluble and able to pass through digestive-tube wall . 59-95

SECTIONS XXVI.–XXVIII. Nitrogen-containing foods or protoplasm builders and the ferments connected with their digestion. Action of alcohol on digestion . . . 96-107

PAGE

Sections XXIX.–XXXI. Comparison of alcohol and true foods. Tea as a beverage 108-117

Sections XXXII.–XXXIV. (*A*). Circulation How the blood reaches every part of the body . . . 118-136

Sections XXXV.–XXXIX. Different constituents of blood and their functions, and the effect of alcohol upon them and upon the muscle of the heart 137-152

Section XL. The nervous system and the deadly effects of alcohol upon it. (This can only be understood through the work done on protoplasm in Sections XI.–XXIV.) . . 153

Section XLI. Alcohol a deceiver 160

SECTION I

Aim.—To discover what are some of the conditions necessary for the burning of a candle, viz. (1) the raising of the temperature of the fat; (2) the presence of oxygen.

Requirements.—Two 2-lb. glass jam jars. 1 good-sized enamel or glass dish. 2 egg-cups with inch-long bits of candle stuck to their bases. Bent glass tube $\frac{3}{16}$-inch bore. Jug of water. Matches. Taper. 2 tin coffee lids. Spirit-lamp. 1 jam jar with paper scale divided into five parts attached, 5 mark to come to base, 0 mark to be below level of dish when jar inverted, as in figure.

(Light the spirit-lamp.) What do you see? What do you feel? What is burning?

(Light the piece of dry wick.) What happens?—It chars, or burns away quickly.

(Compare wick in lamp.) What is in lamp?—There is liquid—methylated spirit.

Will it burn?

(Pour few drops into saucer and light.) Why don't we burn it so?—It would be dangerous and wasteful. So we put the wick into the spirit, it soaks up the fine tubes in the wick, and burns away at top, while more slowly passes up.

What burns in the spirit lamp?—Spirit.

(Describe this candle.) It is wick enclosed in solid fat.

What were candles made of in past times?—Tallow or mutton fat. Usually paraffin fat is used now, but it acts just like animal fat.

(Light the candle.) What happens?—The fat melts and runs up the wick. Like what?—Like the spirit in the lamp.

What happens when the candle fat burns?—You see light and feel heat.

If you burnt the fat in your body it could also give light and heat.

What is wanted before the candle will burn?—(1) Fat; (2) wick; (3) heat from a match flame.

Why don't you have to go on holding this flame to the fat to make it burn?—The flame makes a little fat hot enough to burn, and this *in burning* makes some more hot enough to begin.

Do you know any other things which don't burn usually because they are not hot enough, but burn all up if you make a piece of them hotter?—Yes. Paper, wood, coals, as in fire.

Why do they go on burning when the match flame is removed?—Because their own burning makes enough heat for next bits to burn.

Is anything else wanted in order to make the candle burn besides fat, wick, and heat of match?

If you burn the candle in a closed jar and then in an open jar, will there be any difference? (Collect guesses from children.) We will do an experiment to find out. (Let the children suggest how, and two of their number do the experiment as follows: Set up two wide-mouthed 2-lb. jam jars with an inch of candle at bottom of each; light both candles at once and cover one jar with a square of cardboard.)

Why did the candle go out in the closed jar?—Children will guess. It had used up the air.

That is only a guess. How can we find out? (Get children to suggest and get experiment set up as follows:)

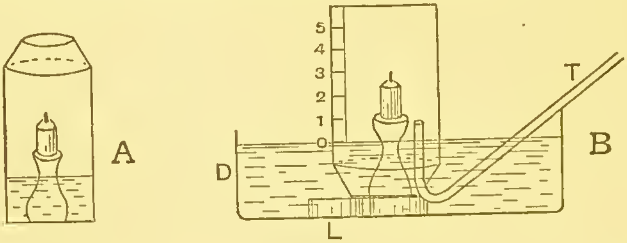


FIG. 1.

M, put 2 inches water in 2-lb. jam pot. Turn an egg-cup upside down in it, having stuck an inch of candle on its base. Light the candle.

N, put the water in dish D, two coffee tin lids L, inverted egg-cup with candle standing on one lid. Invert jam jar over candle with its edges resting on tin lids.

Is the water in the jar at the same level as outside ? Why not ?—The air in jar won't let the water rise.

Push wide glass tube T under the jar so that both ends are above water (see Fig. 1).

What happens ?—The water rises in the jar to the same level as outside.

Why ?—Some air has escaped out of T.

Add water to the dish till the level inside and out is just at mark 0 on the scale.

If I suck the air out at T, what happens to the level of the water ?—It rises.

When I move my mouth from T, what happens ?—The level falls again to 0. Why ?—Because the air has rushed in at T again and pressed the water down. If I put my thumb over T, the air cannot get out or in.

Remove the jam jar, not allowing any water to get into the tube T. Why not ?—The water will seal up T so that the air in the jar no longer communicates with the air outside.

(Light the candle.) Carefully replace the jar exactly as before. The water will rise inside at once to 0, and that instant I close the outer end of T with my thumb.

Watch ! What happens ?—There is dew on the glass. There is soot on the glass. The candle flame dies out. The water rushes up into the jar.

G, come out and tell the others how high it has risen.—Nearly to mark 1.

How much air has gone then ?—Nearly $\frac{1}{5}$th.

(*N.B.*—Candle in burning thus always goes out before it has used up all the oxygen, which is $\frac{1}{5}$th of the total air present.)

What has happened to the candle in A ?—It went on burning.

Results.—The candle in A (open) went on burning. The candle in B (closed) soon went out, and the water rose in the jar. Dew formed on the jar at first.

Why did the water rise ?—Something must have gone out of the jar, and the water came in to take its place.

What was in the jar ?—Air. Part of this air has joined with the fat and its place is taken by the water. There is other gas in the air which won't join with the fat, so it remains in the jar.

Why did B candle go out ?—It had used up most of the air which is good for burning. Burning is the union of fat with that part of the air.

The part of the air which joins with fat is called *oxygen.* The part of the air which won't join with fat is called *nitrogen.*

Which gas did the fat use up in burning ?—Oxygen. Was there as much oxygen gas as nitrogen in the jar ? How can you tell ?—The water would rise half-way if oxygen = nitrogen.

Did it ?

N, come out and see. Do experiment again.

Water rises to between marks 0 and 1. Apparently there is nearly four times as much nitrogen as oxygen.

Summary.—Air contains two gases—oxygen and nitrogen. The oxygen is about 1 part to 4 parts of nitrogen.

Fat in burning takes oxygen out of the air ; when all the oxygen is used the fat can no longer burn.

Children draw figure to illustrate the experiment done.

SECTION II

Aim.—To discover (1) that magnesium in burning requires oxygen just as candle-fat does; (2) that the white powder formed when magnesium burns is a compound of magnesium with oxygen.

Requirements.—8 inches magnesium ribbon. Matches. Glass tube 3 inches. 2-lb jam jar with scale. Bent glass tube $\frac{3}{8}''$ bore. 2 coffee tin lids. Dish. Balance. 2 evaporating dishes. Sand. Bunsen burner flame. (*N.B.*—If no gas is available and the magnesium ignition and weighing cannot be carried out, children must have method and result explained.)

Look at figure drawn last lesson; think over what we found out for two minutes.

What two gases does air contain ?—Oxygen and nitrogen.

How could you remove oxygen from a lamp chimney ?—Cork it and place it over a lighted candle. The fat then burns out all the oxygen.

When other things burn do they use up oxygen ? Have you ever seen magnesium ribbon burn ?

(Burn 2 inches, poking one end up a glass tube to serve as holder. Hold over brown paper.)

Was there as much light as with the candle ?—More light.

What is left ?—A white powder. (Pass brown paper round with piece of magnesium and the white powder.)

When magnesium burns does it use up oxygen ? Can you suggest an experiment to find out ?

The child who made the best drawing last lesson can come out and do this experiment.

Magnesium ribbon to be pushed into end of T inside jar; jar on coffee lids. Tube T to have no water in it. Level of water to be at 0 inside and outside jar.

Remove the jar. Set light to the magnesium. Replace the jar very quickly, and put your thumb over T.

What happens ?—The magnesium burns. The white powder falls on the water. The water rushes into the jar, and *when cool* stands between 0 and 1.

Did you see any wet or soot on the jar ?—No.

Magnesium when it burns is like fat and joins with oxygen of air, and removes it from the jar, so that the water nearly fills the $\frac{1}{5}$ of jar which oxygen formerly filled.

Can you suggest what the white powder is ?—It is the magnesium and oxygen joined together. A gas you can't see and a silvery solid when joined give you this white powder.

On Board: magnesium + oxygen = magnesium oxide.

If true, and we weigh the magnesium before burning and collect all the white powder and weigh it after burning, which will be the heaviest ?—The white powder, since it is magnesium + oxygen. (Children to suggest just how to do this.)

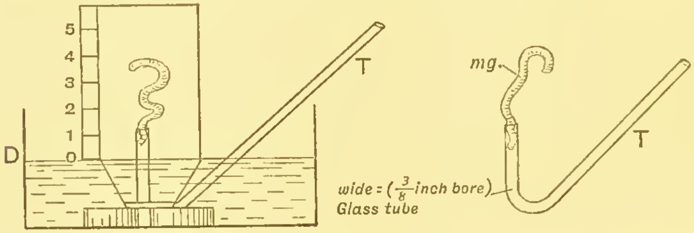


FIG. 2.

C, come out and do exactly what we tell you; others watch and write down how we answer the question.

Does the white powder weigh more than the magnesium ?

On one scale-pan of the balance place one crucible with lid containing loosely coiled magnesium ribbon, and in the other scale-pan place sand to counterbalance it exactly.

Remove crucible with magnesium and lid and heat over a Bunsen flame with the lid on. Leave to cool, remove lid, admitting more air. Let children see that some of the ribbon is a white powder now.—Why do we put the lid on before heating ?—To prevent the white powder escaping. Replace the lid and heat till practically all the magnesium has gone white and powdery. Allow to cool. Stand crucible back on its pan. Which is now the heaviest ?

So white substance in the crucible is heavier than the magnesium put in. Why ?—Magnesium has joined with the oxygen of the air.

SECTION III

Aim.—(1) To discover that the oxide formed when candle-fat burns in air is a gas; (2) to discuss how carbon might be made to burn in some way that will show what kind of oxide it forms.

Requirements.—2 candles. 2 jam jars with cardboard lids. Water. Hard glass tubing. 4 test-tubes. Lime-water. Litmus solution. String. Scissors. Carbon. Matches. Blotting-paper.

What was formed when magnesium was burnt in air?—A white powder; we call it magnesium oxide. Why, do you think?

When a candle was burnt in air, what was formed?—We did not see anything, but we know oxygen of air was used up and the fat of the candle disappeared. An "oxide" must have been made by the union of fat and oxygen. Why cannot we see this oxide?—Can't see air, or the gas that balloons are filled with (hydrogen).

Perhaps the oxide made when a candle burns is a gas like these. If so, why did the water rise in the jar? Should not any gas formed take the place of the oxygen? How could it disappear? How does sugar disappear when water is added to it?

If the gas formed is soluble in water it will dissolve as it is formed, and occupy no space. How can you tell if this happens?—The water will be changed perhaps, and may have some properties of the gas, just as sugar makes water sweet.

If a gas is formed when the candle burns in air it will perhaps have dissolved in water and changed it.

This is an experiment to show you that it has done so. We will add something to the jar in which the candle burns which can be changed by the gas.

Here I have a test-tube $\frac{3}{4}$ths full of a blue-coloured liquid we call litmus solution.

Here is another, $\frac{3}{4}$ths full of clear lime-water solution.

The one is just litmus and the other lime dissolved in water.

M and *N* come out and do an experiment.

M will pour the lime-water into jar M.

N will pour the litmus-water into jar N.

What shall they do next ?—Put piece of candle in each jar with string on bent wire to pull it out by. Light it and place in the jar.

(*N.B.*—Be sure first of all that the candles burn properly, and don't let them be rolled in the liquid when placing them in the jars.)

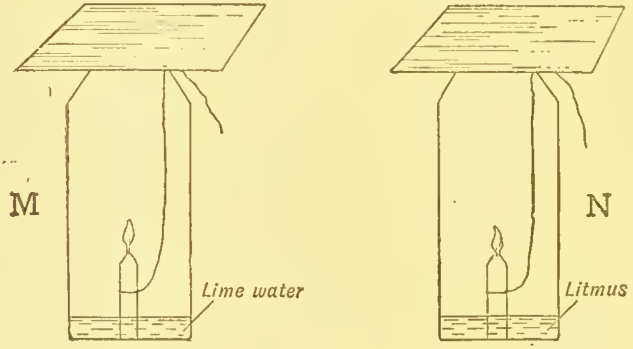


FIG. 3.

They burn up brightly. What are they using ?—Oxygen from the air.

Put a cardboard lid over each, and hold it down. What happens ?—After a minute the candle goes out. Why ?—It has used up nearly all the oxygen.

Now two others, *G* and *F*, come out and finish the experiment.

Pull the candle out of each jar, closing it with the cardboard at once. Shake the litmus and lime-water so that they roll all round the sides of the jar. Do you see any change ?

Compare with these other two test-tubes, one with litmus and the other lime-water, such as we started with. Pour the litmus and lime-water back from their jars into their test-tubes. Hold the litmus against white paper, the lime-water up against the light.

G and *F* take them round so that every one sees.

Result to be *written* down by every one. Then *A* tell me what has happened to the lime-water.—It has turned milky.

Any one, anything else? What has happened to the litmus?—It has turned from blue to purplish pink.

What sort of gas is made when candle-fat burns in air?—A gas which (1) dissolves in water; (2) turns litmus from blue to pink; (3) turns clear lime-water milky.

What else do you know that burns in air?—Paper, wood, coal.

Ordinary coal contains some sulphur and other things mixed with it, but the greater part of it—the part that is black—is *carbon.*

Here is some pure carbon. Will it burn? And if it does, what sort of oxide will it form? So far we have got by burning, (1) *candle-fat oxide,* a gas, and (2) *magnesium oxide,* a white solid.

What might you expect with carbon?—It's quite a different-looking body, and you will expect a quite different oxide, which we would call carbon dioxide.

How shall we get the carbon to burn or oxidise, *i.e.* unite with oxygen?—It does it in the grate, of course.

Why do we use match, paper, and wood before we finally get the coal to unite with the oxygen and so "burn"? What do you do with the match?—We rub it on a rough surface.

What does that do?—It makes the phosphorus on the end warmer, and phosphorus, when it is a little warmer than our air usually is, catches fire, *i.e.* burns.

What is the phosphorus doing, do you think, when it burns? —Uniting with oxygen. Making an oxide.

But while it burns it gives out far more heat. How do we use that heat when we want a fire?—By raising the temperature of the paper, *i.e.* making the paper hotter.

Then what happens?—The paper burns.

Which burns at the lower temperature—the match-head or the paper?—The match-head, phosphorus.

Can you get paper to burn by rubbing on a rough surface?

(Every child have a piece of blotting-paper and rub on the rough surface on which match struck. Compare with similar piece not rubbed. Pieces rubbed are quite warm.)

Are they warm enough to begin to burn?—No. But that amount of heat is enough to start the phosphorus burning.

When the phosphorus begins to burn, does it get hotter than before ?—Yes, and now so much hotter that it raises temperature of paper enough to make *it* able to burn.

Then what happens in our grate ?—The burning paper gives out enough heat to warm the *wood* up to the temperature at which it can burn.

Wood and paper are really made of much the same material. It is as though you had taken many layers of paper and pressed them all together very tightly to make your wood.

Why should the wood, then, want more heat to make it burn ? Besides a certain temperature, what does any body want before it will burn ? (Remember candle in *closed* jar, magnesium in *closed* evaporating dish.)—Plenty of oxygen. With the *wood* only the outer surface is reached by the oxygen. Only a few particles on the outside of the wood are made hot enough by a match flame to burn or char, and the heat from them is not enough to make the next particles catch fire. Paper has much more surface for its thickness than the wood ; a large number of particles of the paper can be oxidised and burn at once, giving out much heat all at once.

What happens if you roll paper up into a tight ball and hold a lighted match to it ?—Burns on outside only. Why ?—Air doesn't get to inside ; but if you drop the same ball into middle of a hot fire it does burn up, because the outer layer oxidises very quickly and completely and doesn't leave a protecting layer of black carbon on outside.

So what are the two things needed for any substance to burn ?—(1) Oxygen ; (2) a certain temperature or hotness.

Is this temperature the same for match-head, candle, wood, etc. ?—No.

Why can we use a match flame to light paper ?—Because heat given out by the flame raises temperature of paper to that at which it can burn.

To come back to the carbon, what two things must we give it to make it burn ?—(1) Plenty of oxygen ; (2) " raise its temperature " to that of a hot fire (or make it as hot as a hot fire).

Think over how we shall do this next time.

SECTION IV

Aim.—To discover that the gas formed when carbon burns is the same as that formed when candle-fat burns.

Requirements.—Spirit-lamp. Blowpipe. Test-tubes of litmus solution and of lime-water. 4 inches rubber tubing. Bent glass tube arms = 2 inches, diameter $\frac{3}{16}$ of an inch. 2 bent glass tubes; long arm to reach nearly to bottom test-tube. Clip. Carbon. Copper oxide. If Bunsen flame used, *hard* glass tubing must be used. Dish of lime-water.

Last lesson we discussed what was needed to make this carbon burn. Write down what we decided.

How shall we get (1) plenty of oxygen mixed up with the carbon; (2) heat of a hot coal fire? Also (3) we want to be able to collect the carbon dioxide which we expect to have formed.

How shall we get the heat?—By a spirit-lamp flame. But this is not very hot. Suppose I blow into the middle of it with this blowpipe; what am I getting into middle of flame?—More oxygen. Will that make it hotter?—Yes; particles which are in the middle can't get much oxygen, so they don't burn so quickly. The more particles there are burning at once, the more heat.

(*N.B.*—If you have a *Bunsen*, use it here and explain its working, only then quite the hardest glass tubing must be used for the experiment later on, or will melt.)

Even using a blowpipe to oxidise all the spirit particles does not make so hot a flame as the fire. Still we will try.

(Heat some carbon in a test-tube over a spirit-lamp flame, using the blowpipe.) It does not burn away, or change like magnesium. (It will smoulder.) If we could manage to give it a better supply of oxygen, perhaps it would oxidise even at the temperature we can get with a spirit-lamp and blowpipe.

I will show you how we *can* give the carbon more oxygen than the $\frac{1}{5}$ part that is in the test-tube.

Here I have an oxide of copper. What is it like?—A black powder. If I call it oxide of copper, what is it made of, do you think?—Copper and oxygen.

If I mix a little copper oxide and carbon together, what three things shall I have all close together?—Copper, oxygen, carbon.

The oxygen is nearer the carbon than if I heat a little mass of carbon with only the surface-layer open to the air, but the copper is holding on to the oxygen. If we heat, perhaps the carbon may be able to steal the oxygen away from the copper. If so, what would you expect the copper to look like?—Brownish-red colour. (Here let a child come out and heat two parts of copper oxide with one part carbon in a piece of glass tubing bent as shown, and held by clip C. Teacher to use blowpipe. Others write down what is done.)

(After two or three minutes allow to cool and pass round. Let each write down what is seen.)

Some brownish-red copper has appeared on the glass. What does this show?—Carbon has taken away some oxygen from the copper and it is left alone.

But we also want to find out if the carbon dioxide which has been formed (1) is a gas or solid; (2) makes any change in litmus; (3) makes any change in lime-water; (4) can you see anything else left in tube which might be carbon dioxide?

I arrange it like this:

Draw on Board. What do you think is here at A?—(Copper dioxide and carbon in proportion of 2–1.)

What is in test-tube T?—(Lime-water; and then in another litmus.)

What will happen if a solid oxide of carbon is made?—(Will stop at A.)

What will happen if a gas, carbon oxide, is made?—(Will be pushed over into T.)

Why a clip at C?—So that gas can't escape into air.

(Describe what she does while the child who has answered best comes out and sets up the experiment.) Mix up carbon and copper oxide well; take off rubber at C, and push the mixture in with a stiff bit of paper. Put on rubber and clip.

Arrange as in figure with long arm of second tube dipping into lime-water.

I will now use blowpipe. What do you see ?—Bubbles of gas come through tube in T and pass up to the surface. Will you expect the first bubbles to make any change in lime-water ? Think. What are they ?—Just air which is being heated and so made to move over.

(*N.B.—To teacher.*—Be careful to remove end of delivery-tube D out of liquid in test-tube if stop heating, or air in delivery-tube cooling contracts, cold liquid is drawn up delivery-tube, and running down upon hot glass, at A cracks it.) After heating strongly what do you see ?—The lime-water is milky. This reminds you of another oxide. Which ?—The candle-fat oxide.

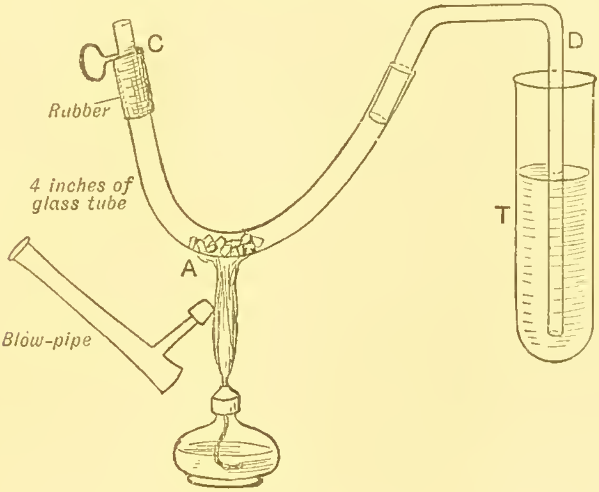


FIG. 4.

What else did that oxide do ?—Turned blue litmus solution pinkish.

Here is a test-tube nearly full of blue litmus. What shall I do with it ?—Put the delivery-tube into it instead of into lime-water. Better put in a clean delivery-tube, because we don't want to add drops of lime-water as well as the gas to the litmus.

(*N.B.*—Lime-water turns pink litmus blue.)

What happens ?—The litmus turns pink. So this gas from carbon and copper oxide has done the same things as the gas from candle-fat, and it is in fact *the same gas.*

(Stop heating, put tube to cool.)

(Children describe what they have done and make drawing. Pass cooled tube round.) After all have seen : What did you notice ?—Shining copper on glass.

Summary on board to be worked out by class and then copied.

" Carbon when it takes oxygen from copper oxide makes carbon dioxide, a gas which turns lime-water milky and blue litmus pink. It is the same gas that is made when candle-fat is oxidised."

I will leave a flat open glass dish of lime-water near the coal fire till next lesson. Can you think what may happen ?

(*N.B.*—Leave enough so that all is not evaporated.)

SECTION V

AIM.—To discover (1) that human beings breathe out carbon oxide gas; (2) that magnesium will burn in it. (Another example of the decomposition of one compound by the action of another substance comparable to copper oxide and carbon.)

REQUIREMENTS.—Preliminary to V. Preparation of jars of carbonic acid gas. The children need not see the teacher prepare this, though it makes a good lesson if there is time.

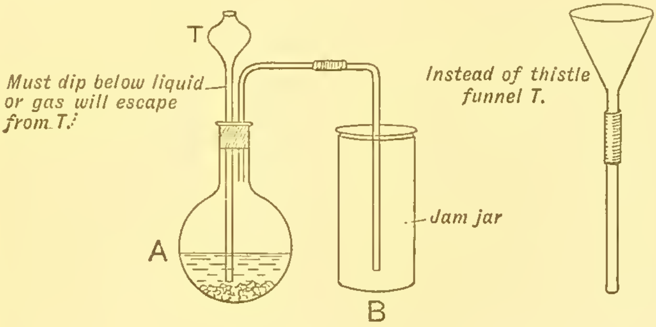

T
Must dip below liquid or gas will escape from T.
Instead of thistle funnel T.
Jam jar
A
B

FIG. 5.

Wanted.—Small pieces marble. Spirits of Salt (HCl). Water. Thistle funnel or filter. Glass tube and indiarubber tubing. 3 jam jars with greased glass photo plates to cover. (Narrow jars better than wide-mouthed variety.) Carbon dioxide preparation.

About 1 oz. of small *pieces* of marble in A, water added, and then equal volume of hydrochloric acid (spirits of salt) poured down thistle funnel T. Gas given off will collect in B, and by holding taper to mouth of B will know when it is full, since taper will be extinguished. Then cover with a greased glass plate or saucer. Carbonic acid gas is heavier than air, and so can be collected in this way. Its solubility in water prevents rapid collection by upward displacement over water.

4 test-tubes ¾ full lime-water. 4 test-tubes ¾ full blue litmus solution (blued by drop of lime-water). 2 jars carbon dioxide gas covered with

greased glass plates. 3 cardboard covers with glass rods pushed through centre, each carrying 3 inches coiled magnesium ribbon.

What has happened to the lime-water we left near fire last lesson ?—It is filmy on top. Why ?—Our coal in burning has been oxidised to carbon dioxide which has passed into the lime-water and turned it milky.

(*N.B.*—Milkiness also due to the carbon dioxide breathed out.)

Will anything else turn lime-water milky ?

Here are three test-tubes ¾ full of clear lime-water. Three children in the middle of each row take one and breathe out into it, getting all the breath out you can. Breathe in ordinarily and breathe out again into the tube. Do this for five minutes. Child on each side watch lime-water ; others write what is being done. Any one who has finished a good account will be allowed one of these three test-tubes of lime-water or litmus solution to breathe into.

What is result ?—Lime-water turns milky.

What does this show ?—We breathe out at any rate some carbon dioxide gas.

We think that carbon dioxide gas is made of carbon and oxygen, which seems strange, for carbon is a black solid, and when it is joined to the oxygen it becomes invisible. Here I have four jars ; two I have filled with the carbon dioxide gas, two with air.

Can you see anything in either ?—No. How can you tell which one contains the carbon dioxide ?—Add lime-water to one, litmus to other.

(Four of you can come out and try.)

How can you prove that the invisible carbon dioxide contains carbon ?—Can only see the carbon if we take the oxygen away.

If you heated copper and put it in jar of carbon dioxide gas, will it take oxygen away ?—No. We saw that carbon takes oxygen from copper.

What other metal easily joins with oxygen ?—Magnesium.

If we make magnesium begin to burn in outside air first, will it go on burning in carbon dioxide gas ? If it does, what must it be doing ?—Stealing the oxygen from the carbon.

Three children come out and do the experiment. (Keep finger on top of glass tube carrying magnesium if not sealed off.)

Some one tell these three children what to do.

"Light magnesium, slide away greased glass plate, and plunge burning magnesium into jar of carbon dioxide gas, bringing cardboard cover down on top of jar."

Result. — Magnesium goes on burning for a minute.

(Three girls take jars round class.) What do you see ?—Black and white powdery material.

What is white powder ?—Magnesium oxide.

What is black powder ?—Carbon.

What has happened ? — "The carbon has lost oxygen, which has joined with magnesium instead."

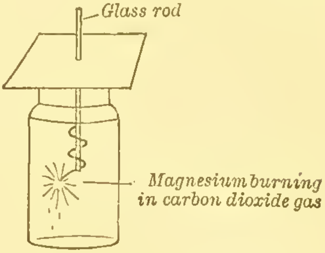


FIG. 6.

So proved that carbon dioxide gas contains carbon.

SECTION VI

AIM.—(1) Revision of carbon dioxide gas; (2) to discover that suet an example of animal fat yields carbon dioxide gas and water when oxidised.

REQUIREMENTS.—Jar with tablespoonful lime-water. Test-tube $\frac{3}{4}$ full lime-water. Lard or suet or animal fat. Evaporating dish. Spirit-lamp. Copper sulphate. 3 bent glass tubes. Crumbled fat. Copper oxide. Indiarubber and clip. Test-tubes of lime-water and litmus solutions.

Look back at your notes of last lesson. *M*, read what you have written.

What then did we show?—That colourless carbon dioxide gas does contain carbon.

How have we obtained carbon dioxide gas?—(1) By heating carbon and copper oxide; (2) by burning coal in grate; (3) by breathing out; (4) by burning candle fat.

What then must there be in candle fat and in our bodies to make this carbon dioxide gas?—Carbon and oxygen.

There must be carbon in the candle and oxygen outside.

There must be carbon in the body and oxygen in the air breathed in.

Why should not carbon dioxide breathed out be just the carbon dioxide you have already breathed in, for all air contains a little carbon dioxide? (See experiment in Section V.)

Obviously much more is breathed out. Let one child shake up a few thimblefuls of lime-water in an open jar for the same time that another breathes into and shakes up a test-tube $\frac{3}{4}$ths full. The latter gets milky long before the other shows the least trace.

This then shows that carbon dioxide gas is made in the body, and that therefore carbon is present in some part or parts of it. How could you show that carbon is present in the fat of a candle?

Here I put this white dish into the centre of a candle flame.

What do you see on the dish? What did we see on the bottom of jam jar when we inverted it over the burning candle?—Soot, which is pure carbon.

Why do we get soot in the flame?—Oxygen does not get into all parts, and also the cold surface of the dish makes it too cold for the carbon and oxygen to join, and so all the carbon there is not oxidised to carbon dioxide gas.

Why can't you see the carbon in candle fat?—Because it is joined with other things.

What other cases have we had where joining one thing to another has made a new thing, not the same as either of the two things which we joined together?

Magnesium (a silvery metal) joined with oxygen (an invisible gas—which means a gas we cannot see) and formed a white solid.

Carbon (a black solid) joined with oxygen and formed an invisible gas, but a gas different from oxygen.

So in fat, carbon is joined with something else, in fact two other bodies, and makes a white solid. [In candles not made from tallow only carbon and hydrogen present, no oxygen.]

One of the bodies is oxygen itself, but only a very little, not nearly enough to oxidise all the carbon.

See what happens if we heat suet.

(Piece of suet size of a small bean broken up in evaporating dish. Heated with spirit-lamp flame. Ditto in test-tube.) Two girls out to watch and report to class. What happens?—Fumes, melts, bubbles, blackens, and smells.

Can we find out what is coming away in those fumes?

Hold a cold glass surface over the dish.

Film over the surface. Rub with a clean white sheet of paper.

What do you get (holding sheet up for class to see)?—A grease spot.

What has come away in those fumes?—Some of the fat unchanged.

(*N.B.—If children suggest water, test* for it by dropping white copper sulphate on the glass, as it cools there may be a trace of water.) What else has happened?—Some carbon, the black part, has been extracted from the fat, because other substances have been broken away from the fat, leaving it behind. When did we get carbon left behind before ?—When we took oxygen from carbon dioxide gas with magnesium. But as we are heating in air, why doesn't the carbon take *up* oxygen ? Remember we had to give it plenty of oxygen and much heat when we wanted it to oxidise. (Sections III. and IV.) Possibly other substances in fat have been oxidised, but some carbon has not been able to get hold of any oxygen and so is seen as black carbon. How do you know it is carbon ?—Only because I tell you so, but if we had time and materials we could prove it.

Can we get suet to oxidise and give off carbon dioxide gas ? How shall we try ?

We want—

(1) To provide plenty of oxygen.
(2) To raise the temperature.
(3) To pass any gas into the lime-water.

(Arrange as in experiment of oxidation of carbon, rubbing up the suet with copper oxide.)

What happens ?—Gas comes off, turns lime-water milky and blue litmus pink. There is a deposit of copper on the tube.

(Before this lesson take some quite small crystals of copper sulphate and heat in test-tube until they lose water and turn white.)

We want to show that something else besides carbon dioxide gas is made, viz. water when fat is oxidised ; just as we have to test for carbon dioxide with lime-water, so must test for water by something it does that nothing else can do.

Here is a white solid in this test-tube. (Some of the white crystals of copper sulphate.)

M, come out and drop some water (a drop) on the white solid.

(Pass test-tube round in silence and every one write down what water has done to the white solid.)

What have you written ?—" Water has turned the white solid blue."

Does every one else agree ?—It is the only liquid which does this.

How shall I use this white solid to show that when fat is oxidised water comes off ?

I have a bent glass tube here with white solid at one end. Attach as in figure at T in place of delivery tube to lime-water.

Children all describe: “How we show that fat when oxidised gives off carbon dioxide and water.” Cool the tube, pass round.

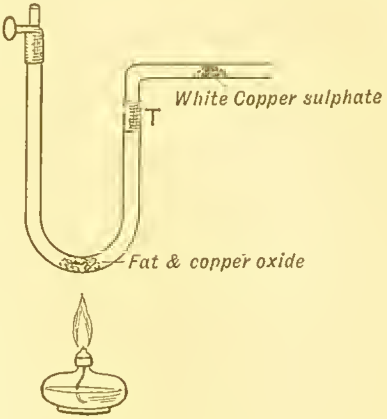


FIG. 7.

What is fat, then ?—Fat in your own body or fats from other animals’ bodies are much the same.

(Part in brackets to be left out if children too young. See Preface.)

*(If you could take a particle of fat the size of this dot on board and break it up into tinier and tinier bits, much, much smaller than the smallest you can see, you would come at last to the smallest divisions of all, and would have broken up the particle of fat into parts which we call molecules. In a piece of fat the size of a pin point there would be millions of these molecules all exactly same size and each made up of exactly same parts. Many parts carbon, 6 parts oxygen, and many parts of a third body we will call “*H.*”) *

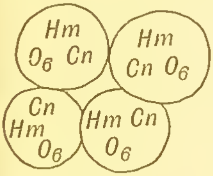


FIG. 8.

We will put an *m* after the H to mean many of them and an *n* after the C to mean a number of them. What shall we put after the O ?—A 6.

Suppose you had millions of molecules like this all side by side on pin point, that would be fat.

What happens when oxidation begins ?—The separate molecules themselves are broken up.

Make a picture of it on board.

(For teacher only : A typical fat would be $C_{51}H_{98}O_6$.)

We will put in C’s for carbon, O’s for oxygen, H’s for the third body ; mustn’t put in more than 6 O’s.

It won’t show all O’s in this view ; some behind with others of the C’s and H’s. Really all C’s, H’s, and O’s are definitely placed with regard to each other. We will not bother as to that.

Then all round outside such a molecule we suppose we have oxygen in the copper oxide.

Then the carbons unite with some of the O of the copper oxide and go off; the H's with some of the O and go off as water; and copper is left alone. Some of the carbon will very likely not get hold of any oxygen and will be left alone as soot.

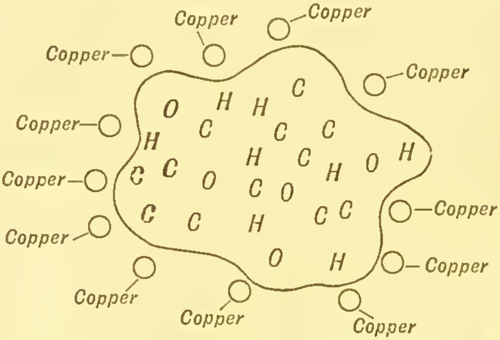


FIG. 9.—One view of a Molecule of Fat with Copper Oxide Molecules all round it.

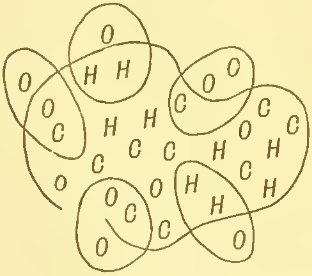


FIG. 10.

Did you notice the smell when we were oxidising the fat?

If there are some carbons and hydrogens and not enough oxygen to make them into carbon dioxide and water, they will be left together and make another substance which gives the nasty smell.

If enough oxygen is present and the fat is heated sufficiently, we get only carbon dioxide gas and water.

Summary.—Fats, including human fat, can be oxidised when strongly heated with copper oxide, and then give carbon dioxide and water.

$$\left[\begin{array}{l} C_{51}H_{98}O_6 + 145O = 51CO_2 + 49H_2O. \\ \quad\text{Fat} \quad + \text{Oxygen} = \text{Carbondioxide} + \text{Water.} \end{array}\right]$$

SECTION VII

AIM.—To discover that slow oxidation occurs at ordinary temperatures outside the animal body.

REQUIREMENTS.—4 test-tubes. 2 dishes of water with cardboard lids. 2 glass rods same length as test-tubes. 2 lengths of 2 in. of magnesium ribbon. 2 corks for test-tubes. Iron filings. Muslin. String. 4 coffee tin lids.

Leave out part between asterisks if necessary as in VI.

* (What are molecules of fat ?—The very smallest parts into which fat can be broken up, and yet still be fat. All the molecules are the same size and exactly alike.

What is each molecule made up of ?—A large amount of carbon and another body H and a little, very little oxygen.

If you oxidise by heating with copper oxide, what happens ?—Each fat molecule is broken up ; some carbon joins with the oxygen and goes off as carbon dioxide gas : some goes off with the H and forms H oxide, or water ; and some carbons and H's can't get hold of enough oxygen and so remain together and make with the little oxygen they do get hold of, a nasty smelling stuff.) *

What do you get when a fat is oxidised ?—Carbon dioxide gas and water.

How else have we formed carbon dioxide ?—By breathing out.

Do we also form water by breathing ?

Breathe on (1) mirror ; (2) white copper sulphate.

We certainly breathe out water.

Have we any fat in our bodies ?—Yes.

Do we eat fat ?—Yes.

How then *may* we make the carbon dioxide gas and water we breathe out ?—By oxidising fat in the body.

But our bodies are not as hot as spirit-lamp flame, and can anything be oxidised without heat ?

Let us try with the magnesium we oxidised by burning.

N and *M* come out and do experiments for us. Others watch and criticise. I want you to arrange to try if magnesium will oxidise when just left in air, but some magnesium is to be dry and some damp.

Take two lengths (2 in.) of quite bright magnesium ribbon and two test-tubes. Dry one very completely by passing through the flame, put one length of magnesium in it and cork.

Take the other test-tube and half fill it with water and invert (by pressing thumb over its end) in a dish of water so that water stands half-way up tube. Stick the second 2 in. of magnesium in end of a glass rod and poke it up the test-tube thus :

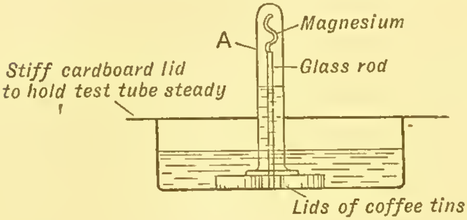


FIG. 11.

(Draw figure on board.)

Every one describe what we have done.

Now *G*, read your account. (Call on children till you get two good accounts, then ask those two to come out.)

G and *H* are to arrange another experiment to show if these bright iron filings will oxidise slowly or not.

G shall do the dry filings experiment.

H shall do the wet filings experiment.

How shall we arrange dry one ? Some one tell her.

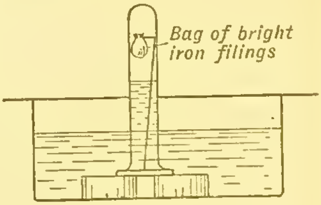


FIG. 12.

Dry the test-tube. Put in the filings and the cork.

How shall *H* arrange her filings to be poked up above the water in a test-tube, like wet magnesium experiment ?

Tie up in muslin ? Can air and water get through ?—Yes.

Have you ever seen iron change its look in air ? Think of bicycle spokes, sewing-machine wheels not much used, pins, needles.

Every one write down what they *think* will happen during the week in this iron experiment in the two test-tubes.

SECTION VIII

Aim.—See Section VII.

Requirements.—The 4 test-tubes, etc., arranged last lesson. On board, drawing of apparatus as arranged. Jam jar. Fat, *e.g.* suet. Glass rod. Dish of water.

(Have iron experiment one side of room. Magnesium on other.

Have four children come to you early and explain to them exactly what has happened, and then put one in charge of each test-tube.)

I want all of you to see the results of last week's experiment. Six of you are to go to each experiment at a time and have it explained by the pupil in charge. Then go back to your place and write what you see. Those of you not looking at the experiment, draw the figure on the board, and get ready columns as follows to put down results :

Dry Magnesium.	Damp Magnesium.	Dry Iron Filings.	Wet Iron Filings.

(After about thirty minutes all children will have seen all four experiments.)

What had happened to the dry magnesium and dry iron ?—Nothing.

What had happened to the damp magnesium ?—It was a little coated and dull.

The water had risen a little. Why, do you think ?—

Magnesium has joined with oxygen and water has risen to take its place.

Magnesium will oxidise even when only as hot as this room, but very slowly (takes quite a week).

What has happened to the iron ?—It has "rusted," got a red deposit on it. Can you guess why ?—Iron, like magnesium, joins with oxygen, and its oxide is red. Would you say that iron or magnesium oxidises most quickly ?—Iron. What should we have to do to *prove* that the iron has *joined* with oxygen, and not simply lost something (as the fat lost the carbon dioxide), and so been changed to a red body by loss and not gain as fat changed to carbon ?

If it has joined with oxygen, what about the difference in weight between the red oxide and the original iron ?—The red oxide will be heavier.

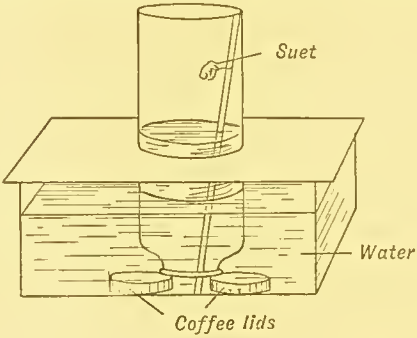


FIG. 13.

How should we find out if it is so ?—Dry and weigh a dry bag of filings before and after. We won't do it, but it has been done often, and always the red substance, the "rust," is heavier than the original filings taken. Also the oxygen used up is always about one-fifth of air above the water in test-tube.

Conclusion.—Magnesium and iron will both join with oxygen at ordinary temperatures and form oxides, but only when water is present.

What would happen if this fat were so left ?—After a time it would "go bad" because the air is full of tiny living things (almost as small as a fat molecule) which attack the fat molecule, and it is oxidised by their help rather in the way the water helps the magnesium and the iron to oxidise. As it goes bad or gets broken up, what will be formed ?—Carbon dioxide gas, water, and other bodies with bad smells. May take some time, but we will leave a piece and see. The living things that live on fat may not be in the air of our room, but we will try.

Set up jam jar as in figure with piece of suet tied to glass rod.

SECTION IX

AIM.—(1) To discover that starch like fat can be oxidised; (2) to discover that the body keeps at a constant temperature above that of its surroundings, and therefore requires a supply of heat energy, which it obtains by oxidation of such foods as starch and fat.

REQUIREMENTS.—U-tube with indiarubber tube and clip. Starch and copper oxide. Test-tube. Lime-water. Copper sulphate. Spirit-lamp. Blowpipe. Matches. Clinical thermometer. Centigrade thermometer 100°.

(*N.B.*—If possible some day before this have a lesson on the thermometer and measurement of temperature.)

We have shown:

1. That fat can be oxidised and gives what?—Carbon dioxide and water.
2. That some oxidations can go on without heat being given greater than that of the body.
3. That the body produces carbon dioxide gas and water.
4. That we need fat, and indeed people have discovered that we don't grow or keep strong without some fat food, such as milk, butter, suet, lard, etc.

So we conclude that fat foods are oxidised by the body. This has been proved by scientists in many experiments. Will any other foods beside fat oxidise readily?

We will try some starch. When do we eat foods which contain starch?—When we eat potatoes, bread, sago, rice, etc.

How shall we try? *M*, come out and do the experiment.

Fit up experiment as with fat, see Section VI. page 18, using *starch* rubbed up with copper oxide instead of fat. Repeat that lesson.

Summary.—Starch oxidises and gives carbon dioxide and water even more readily than fat does.

* (What did the fat molecule have in it ?—Carbon, " H," and a little oxygen.) *

Starch has exactly same things in it as fat, but much more oxygen. If we had time to try *sugar* under similar conditions, we should find much the same thing. It too contains carbon, H, and oxygen, and it oxidises to carbon dioxide gas and water.

Why does the body need foods like fat, starch, and sugar, which it can oxidise ?

Does it want carbon dioxide gas ?—Not at all ; it gets rid of it through the breath, and as we shall see works hard to do so. Carbon dioxide gas is a *waste* product.

Does it want water ?—Very much. We should die without water (see why later on). Water is everywhere in the body, but still if we drank only water and didn't eat fatty or starchy foods we should die. So it isn't for the sake of the water that we eat these foods. What time of the year do you like most suet puddings, or rice, or sweets ? In hot or cold weather ?—In cold.

What do " fasting " men do ?—They get into bed and stay still and keep warm. If they don't they get thinner, *i.e.* use up the fat already on their bodies much quicker and have to stop fasting sooner. Why do they use up fat quicker when they are not covered up ?—Fat, when used up, gives them heat. They want more heat given them when out of bed than when in it ; when they stay in bed they don't want so much heat, so they don't use up fat.

When a bear goes to sleep for the winter, what is he like ?—Very fat.

When he wakes up, what is he like ?—Very thin.

What has happened to his fat ?—He has used it up to keep himself warm.

A coal fire keeps you warm. What is happening to the coal ?—It is being oxidised to carbon dioxide gas. Magnesium ribbon in burning gives out light and heat. What is happening ?—It is being oxidised.

When magnesium ribbon oxidises quietly without a flame does it give out heat ?—You can't see light or feel any heat, but it is *all the time* giving out heat, only very slowly, so that the heat given out passes away to the things around, and no one spot is made hot enough for you to feel the difference.

Whenever any body is oxidised, heat is always given out, though there may be no light or flame.

Now why do you want suet pudding more in winter than in summer?—Because you want more heat and your body can oxidise the suet or any other fat, and in the oxidation heat is given out to your body.

Why must the bear get fat before his winter sleep?—He must be kept warm, and he can oxidise the fat of his body, and heat is given out by that oxidation.

(*N.B.*—Here an intelligent child ought to ask, "But we *gave* heat to get fat oxidised when we heated it with copper oxide. Why was that?" Answer would be:—)

Well, you see the oxygen is rather tightly joined up with the copper, and the heat was to drive them apart, and also to make the carbon hot enough to join with the oxygen. In the body the oxygen, as we shall see, is not so tightly joined up to the thing from which the starch and fat steal it, so you don't need great heat to begin the oxidation.

Oxygen in the body is attached to something that carries it rather like a rider on a horse, and so can easily be pulled away by the fat. Oxygen in copper oxide is like a speck in this granite, only to be got out by blowing the stone to bits. The heat we give practically pulls the copper oxide to bits, so that the fat can pick up the oxygen. The heat given out when the fat is oxidised is much greater than the heat we give the mixture from our spirit-lamp.

Heat given out by coal in oxidising is much greater than the heat of the match we used to light the fire with. We give a little heat energy to start a change from which finally a great deal of heat energy is obtained.

Why does the body need heat?—From its food the body builds up itself. Bone. Muscle. Blood. Brain. It has to change the food then; all these changes only take place at a certain temperature, just as paper only began to burn at a certain temperature.

What else have we had which only changed to something else at a certain temperature?—The match (when heated by rubbing), the candle wick, and fat.

So all the changes in the body by which food becomes body substance only take place properly when you are at a certain temperature. Has your body ever been hotter than it ought to be ? Not only just felt hotter, because you can " feel " hot on the surface and yet when your temperature is taken it is all right.)

Has the doctor ever " taken your temperature " ?

Here I have a thermometer which will take your temperature as the one on the wall takes the temperature of the room. I will wash it by dipping it in this mixture, which has in it a disinfectant (boracic acid saturated solution). Why ?—Might have germs on it and the disinfectant will kill them. And now *M* come out, and we will take her temperature.

(Make child see where the mercury thread is, and then put in her mouth under tongue and close her lips.) Will take a minute and a half for the thermometer bulb to get as hot as her body.

(Take out and show child thread has moved up and reads 98·4° F. if she is normal. Clinical thermometers are marked in degrees Fahrenheit.)

Her body then has just the right amount of heat in it for all the changes that have to go on.

Now *M* must take some exercise till she *feels* much hotter in the recreation time, and then if she will come to me I will take her temperature again. Do you think it will be the same ?

It will, very nearly. If when we got hot by exercise our temperature changed much it would be bad. Why ?—Because our bodies would not work well at any other temperature.

Have you ever really been too hot ? If you have had a fever or influenza, then your temperature was high and your body did not do its work properly and you felt ill.

So you need to be kept at a constant temperature.

But suppose you were not getting fresh heat all the time from somewhere, would you remain at the same temperature ?

If I put a hot poker in the fender, does it stay hot ?—No. Why not ?—Gives off heat to the air and the fender.

For how long ?—Till it is " same temperature," or just as hot as the air or fender.

What is your body doing all the time ?—Giving off heat to its surroundings.

Why ?—Because it is hotter than its surroundings.

How do you know ?—It feels so. That wouldn't prove it but the thermometer does. That thermometer on wall (or Centigrade one teacher has) says temperature of room is —.

G, hold bulb in your hand. Mercury goes up. Why ?—Your hand is hotter than the room. Why then does not your body get colder and colder if it is giving up heat to the room all the time ?—Because the foods like starch and fat and sugar, which you have eaten, are being oxidised in the body and are giving out heat.

Now answer in writing :

What facts make you think that certain foods are oxidised in the body ?

Why does the body oxidise these foods ?

SECTION X

(Only to be taken with children if parts marked (*) in Sections VI., VII., and IX. have been given. If omitted, have a simpler discussion of what happens when water boils, *e.g.* coal oxidised, heat produced, makes liquid water into water gas, this tries to escape, presses on certain parts of the engine, and so produces movement of other parts. Such a lesson will show that heat does produce movement, but will not attempt to explain how it does so.)

Aim.—To explain that "heat is a form of energy" and that heat energy can be transformed into mechanical energy.

Requirements.—Beaker of water. Spirit-lamp. Tripod. Iron wire. Chalk dust. 6 marbles, glazed. Paper groove.

Last lesson we discussed why the body needed heat.

Why does it ? How does it get the heat needed ? What is heat ?

It is difficult to answer. If we can find out what heat *does*, we may be able to understand better.

Here I have a beaker of water. Let us give heat to it and see what happens.

Two people come out and watch closely all the time, and write down what happens. When I say, others can come out to see at certain points. All watch, draw, and write down what the two tell you.

First, tiny bubbles form on the bottom of beaker and then move up through liquid and pass into the air.

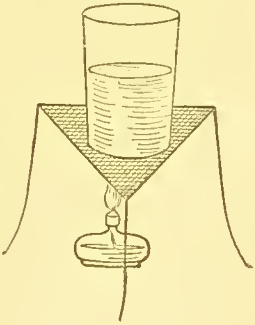


Fig. 14.

What are these bubbles ?—*Air.*

What is air ?—Oxygen, nitrogen, and a very little carbon dioxide gases.

What has water done to some air then ?—Dissolved it, so that you can no longer see it.

Have you ever seen a liquid dissolve anything before and apparently not be changed ?—Sugar or salt in tea and in water. Washing soda in water.

Where else are bubbles forming now ?—On the sides.

All be very quiet. Can you hear anything ?—The bubbles breaking up as they escape into the air.

Heat then drives gases out of water.

At last all the air has been driven out, and now what do you see ?—Large bubbles forming on bottom and breaking there. At last some of these rise to surface and pass off, and finally all the liquid seems to be dancing, and many bubbles pass off at surface, *i.e.* "boils."

What are these bubbles ?—Water vapour or water gas.

(*N.B.*—Difficult to prove to children that the first bubbles are air and the later ones water vapour, must take it on your authority.)

Hold a cold glass plate (*e.g.* ¼-plate from camera, or a tray) over the beaker. What happens ?—Water gas "condenses" back again to liquid water and forms drops.

The difference between the molecules in the water when liquid and in the same water when it has become a gas or vapour is that the molecules in the gas are all moving much quicker than in the liquid.

What is a molecule ? (Recall Section VI.)

A water molecule is the very smallest part of water that exists. Water is in fact made up of molecules all exactly alike, all the same size. These water molecules are incredibly small.

How many do you think there would be in a drop of liquid water that you can just see ?—Millions.

How many in a tiny bubble of the water gas ?—Still millions, though fewer than in a drop of liquid water the same size.

What has heat done to water molecules ?—Has made them move much quicker, so that you cannot see the form the mass of them assume.

If a train rushes by you can't see it so well as if it passes slowly. This does not explain to you exactly why you can't see the gas, but it does depend on the extra rapidity with which the molecules move, just as the indistinctness of rapidly moving bodies like trains or lines drawn on a windmill sail depends on *their* movement.

What has heat done to water?—Made its molecules *move* much more quickly than before.

What is it that moves anything? *e.g.* trees?—A *moving* wind. Stones?—A moving river.

Here I have a line of marbles in a paper groove.

I run another in behind and what happens?—The others all move on. Why?—Marble has passed on its extra motion to the others. If one marble touches another moving at same rate, will it make the one it touches move more quickly?—No; the one behind must move quicker, then can pass on its extra movement to slower one in front.

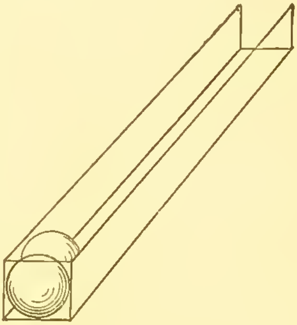


FIG. 15.

Can you tell what heat is from what it does to water?—It makes the water molecules separate and move out of water.

Heat is motion of the molecules of the hot body. When the molecules of one body are hotter than those of another, *i.e.* moving more quickly, then they can pass on their motion. In the case of the boiling of water, we use a spirit-lamp flame, and its heat is the motion of molecules of carbon and gases formed as the spirit oxidises. When these molecules hit against glass of beaker, they make its molecules move faster too; sounds impossible, but it's true that all the time the molecules of everything are always moving. When they get hot, it only means that their molecules are moving faster. The glass molecules pass on their motion to the water molecules, and these move quicker and quicker till, as we have seen, at last some of them become separated from the rest and so form bubbles which pass up to top of water. If you can move lots of things or move yourself about more than most people, we say you are, what kind of child? (*e.g.* if you play at running games or skipping)—An *energetic* child. You have "energy." So we say that the molecules of the flame have energy, and *heat* is the name we give to this kind of energy.

How did we get heat without any light?—By rubbing two pieces of blotting-paper together. Here we had movement producing heat, and as heat is just motion of molecules, we are not surprised that movement leads to appearance of heat.

When you run, you feel hot. Are you necessarily really hotter ?—The surface of the body may feel hotter, but yet the temperature inside, where all important changes occur, remains the same.

(Recall taking of temperature, Section IX.)

Why don't you get really hotter ?—Partly because you give away the extra heat from your body surface to your surroundings. How do you give the heat away ?—Partly as the poker did to the air ; the extra motion of the poker molecules passes on to the molecules of air.

What happens to its speed when one marble runs into another ?—The one begins to stop as it passes on its motion to the other.

What happens to the poker molecules as they pass on their motion to air molecules ?—They slow down. How can you tell poker molecules are slowing down ?—The poker gets "cooler."

Heat is passed on by your body in the same way to molecules of air, chairs, tables, etc.

There is still another way in which the body loses heat though. When you have got very hot, what sometimes passes off from your skin ?—Water in perspiration. What happens to a drop of water when it has got to the outside of your skin ?—Gradually "dries up." Why does it "dry up" ?—The heat from your body passes to it, just as heat from our spirit-lamp flame passed to the water in the beaker. What does the heat do to the drop of water ?—Makes its molecules move faster and faster, and separate from each other, and finally go off into air as separate molecules.

Why can't you see it happening ?—Because the molecules are so tiny (there are millions in smallest drop you can see). And, once they separate from each other they can't be seen.

What do we call a body in which the molecules are so far apart they can't be seen ? (There are still millions in a bubble of gas the size of a pin point, but they are smaller than the spaces between them in a gas.)—A gas.

What is the gas when water molecules are so separated ?—Water gas or water vapour.

What has made water molecules separate and make water vapour ?—Heat from your body. If your body molecules have passed on motion to water molecules, what has happened to body molecules ?—Have slowed down. What do we then say has happened to the body ?—Body is cooler. (Other instances of evaporation of water are, of course, disappearance of dew through heat of sun, drying of clothes by wind.)

When you are feverish how does your skin feel ?—Dry and hard. Why ?—Your body is not working properly and has not sent a proper supply of water out to your skin. What happens to your temperature ?—It goes up. Is this bad, and why ?—The body can't do its work so well, can't use up food to build up bone or muscle or blood, and do all the other work we are going to learn about, except at the proper temperature. Very often the doctor gives medicine then to make you perspire, which helps to cool you down to temperature at which the body can work best.

When is a substance " cold " ?—When it has less heat than other substances around it, *i.e.* when its molecules are moving slowly.

What is heat ?—A form of energy, a movement of molecules which our bodies can feel.

How is this form of energy produced ?—By oxidation.

What kinds of oxidation have we had ?

(*a*) Quick—much heat given off *at once*, and flame or light produced, *e.g.* coal, magnesium, candle fat.

(*b*) Slow—I told you that just as much heat was given off in the end, only more slowly, so it is passed on to surroundings and no flame produced, *e.g.* damp iron filings and magnesium, fatty, sugary, and starchy foods in body.

On Board: " When any molecule is oxidised, *i.e.* joins with oxygen, energy is given out."

If it is a molecule with many different things in it like fat, all of which join with oxygen, much energy will come from one molecule.

If it is a simple molecule like carbon, which has only carbon in it, less energy will come.

When energy comes from a chemical change, such as breaking up of fat into simple molecules like carbon dioxide gas and water, we say the fat had *chemical energy*.

What other form of energy have we had ?—*Heat energy.*

The chemical energy was in the fat molecule, and when that molecule was broken up the chemical energy became heat energy, *i.e.* energy of *movement* of molecules. What happens to that movement ?—It is passed on and so lost to the molecules which were in the fat.

So which has most chemical energy, a fat molecule or the molecules of carbon dioxide gas and water into which it can be broken up ?—Fat molecule.

What can we use heat energy for ?—To boil water and make water vapour.

What is the energy or power of water vapour or water gas sometimes used for ?—To make machinery move.

Have you ever seen water gas move anything ?—A kettle lid.

(Do it if children have never seen.)

Have *you* ever been moved through the energy of boiling water ?—Yes. In a train.

The coal oxidised, the chemical energy becomes the heat energy of the molecules of flame, it passes on to molecules of liquid water which become even more rapidly moving water gas, which presses against and moves iron levers which move wheels of engine round, which move carriages which move you.

Now, children, try and write down that long string of happenings for yourselves.

Head it : " How a chemical change has moved me."

Here then chemical energy became heat energy, but what shall we say the heat energy became ?—It produced movement of collections of molecules all together, moved whole machines, engines, carriages, you.

What do you call a man who has to do with machines ?—A mechanic.

So we call the energy which moves machines " mechanical energy."

Chemical energy, became *heat* energy, became *mechanical* energy.

Shut your eyes and think out the chain of change again.

Now write answer to—

What is energy ? (Only 3 to 6 words required.)—Energy is the power to move or to do work.

A few minutes ago I mentioned *you* among " machines."

A machine is really just something made to turn energy, such as chemical or heat energy, into the more useful mechanical energy which does work for us, *i.e.* moves things in the way we want them moved. Like the engine of a train or the weaver's loom which moves the threads into the position we desire and makes cloth for our clothes or carpets for our floors.

Now was I right when I called you " machines " ?

Every one try to write an answer to this question, and next time we will begin to discuss it.

Why do you think you are a machine ?

For a revision lesson let children answer in writing :

1. Describe what happens when water is heated in a beaker.
2. What is energy ?
3. Why do you think heat is a form of energy ?
4. What is a molecule ?
5. Why does water " dry up " on the skin ?
6. Give one reason why people are sometimes feverish.

SECTION XI

AIM.—To discover (1) that bodily movements are brought about by muscle action which depends for the necessary energy on the oxidation of food stuffs; (2) that alcohol though oxidisable did not supply such energy to puppies.

REQUIREMENTS.—Rabbit's hind legs cut off so as to include the hip bones, and pinned to a board which can be hung from blackboard or passed round. One leg to be intact with muscle attached as in life. The second leg to have the extensor muscle cut away at the hip and freed from the thigh bone. To preserve such specimens pickle in brine (2 pints water and a large handful salt and a heaped tablespoonful saltpetre). Also the bones of a hind leg from which the meat or muscle has been removed. (Both done after boiling the leg.) Figs. 16, 17, and 18 enlarged.

Am I a machine, *i.e.* can I change chemical energy into heat and mechanical energy, and so bring about useful movements?

Movements, running, talking, lifting, breathing, are such movements. Where does energy for such movements come from?—Oxidation of food. What is made in oxidation of food such as starch or fat?—Carbon dioxide gas, and water. Are they any use to the body?—The gas is not and is given out to the air. Water is very useful. Why?—It dissolves foods. It helps to cool the body through perspiration. But the water we drink is enough for these purposes, so why should the body be put to all the trouble of breaking up the food molecules and oxidising them?—Because it needs the energy which is always given out when the bodies are oxidised. Recall heat of coal fire, light and heat of burning magnesium, the flame of burning candle fat. What two forms of energy must the body have?

1. *Heat Energy.*—It keeps at a constant temperature, though in our climate heat must be given up to surroundings nearly all the time. Also the giving off water vapour and

making liquid water from the body into vapour, needs heat, just as the making liquid water into vapour in a beaker required heat.

2. *Mechanical energy* or energy of such movements as the body makes in walking, breathing, etc. What part of the body carries out these movements ? Suppose a blacksmith moves his arms in a particular way for months and years, what are his arms like compared to those of a clerk ?—Much bigger.

Are his bones bigger, or has the fat on them increased ?—Not the fat but something else clothing the bones. What do we call this covering which increases with exercise of the part ?—Muscle. Have you ever eaten muscle ?—Muscle : beef, mutton.

Here is the leg of a rabbit. What is this flesh round the bone ?—Muscle. Hind left leg pinned with inner side next board will show (see Fig. 16) flexor muscle (F) on the left, extensor muscle on the right, with a line between indicating position of a nerve, vein, and artery. The thigh bone hidden by the extensor muscle, which ends in the stout tendon (T) at the knee-cap. When I take hold of this bone (near foot) and bend it up to the left, watch the big mass of muscle above it (extensor). It lengthens. What does the muscle mass above and to the left of this middle line (flexor) do ?—It slackens and thickens. Suppose the leg is bent, how can rabbit straighten it again ?—The right-hand muscle (extensor) will shorten. What does this pull on ?—The long whitish-looking end of the muscle passing over the knee. To what is this attached ?—Upper end of shin bone, which is thus straightened into line with the thigh bone.

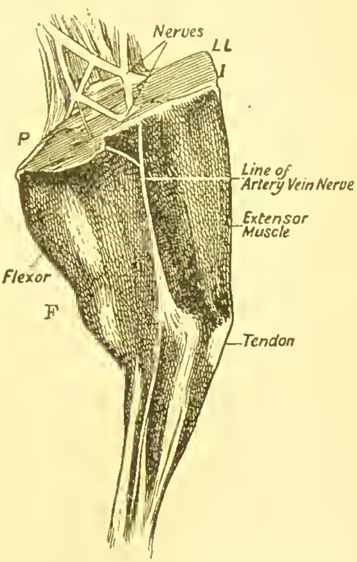


FIG. 16.—Muscles in rabbit's hind-leg.

(Here show the bones of the rabbit's leg.)

When you look at the muscle what do you find covering it ?—A thin transparent layer which serves to help to hold it together. Similar layers run in, enclosing other parts of the muscle. It is rather like these long red threads, each of which I have wrapped round in tissue-paper sheaths longer than the threads, and then put all the threads with their sheaths in an outer sheath of paper. What happens to the ends of the sheaths ?—They all run into one another and twist together, forming a white tough end to the muscle as I make this projecting paper twist up together at the end of my threads. Then this tough end is attached to the bone here. (Lay the twisted ends of the paper sheaths against knee-cap end of shin bone and the sheath with their threads in position of extensor muscle.)

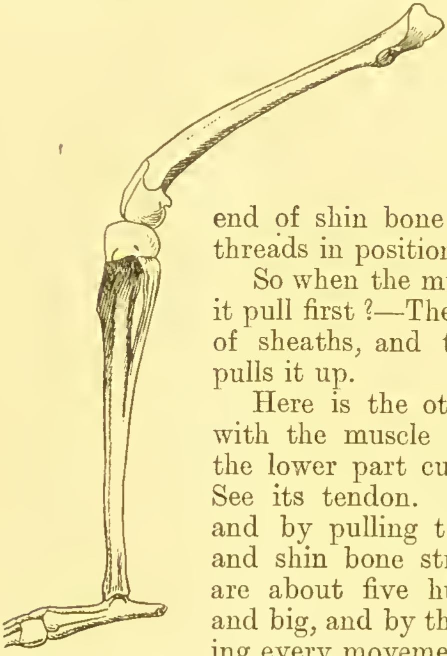


Fig. 17.—Bones in rabbit's hind-leg.

So when the muscle shortens, on what does it pull first ?—The tendon, as we call the rope of sheaths, and this pulls on the bone and pulls it up.

Here is the other hind-leg of the rabbit, with the muscle that shortens to straighten the lower part cut away from the hip bone. See its tendon. Some pupil can come out, and by pulling the muscle pull the tendon and shin bone straight. In your body there are about five hundred such muscles, little and big, and by their shortening and lengthening every movement is made.

Now let each of you hold the front of the right arm between elbow and shoulder, holding the right arm extended straight out. Move the lower part of arm from the elbow (hand) upwards towards shoulder.

What do you feel ?—A hardening. Something seems to swell. What is it ?—Your " biceps " muscle.

(*N.B.*—For good illustration of muscle action, see Ravenhill, page 155.)

Drawings on board of biceps muscle, with the forearm extended and flexed.

Looking at these two drawings, what would you say had made forearm bend up ?—Biceps muscle gets shorter and of course thicker, and so forearm is pulled up. *We say the muscle has contracted or shortened.* What happens when forearm falls ?—*Muscle has extended or lengthened.*

Before the muscles move what must they have ?—Energy. Where do they get the energy from, do you think ?—From the oxidation of the food materials. So in some way the food you eat must get carried to the muscles. Later on we shall learn how. Does it matter if our muscles move readily and quickly ? Who does the most work, the road-mender or bricklayer who has good, firm, strong muscles which lengthen and shorten readily, or the other man with "flabby" muscles ? What gives strong muscles ?

1. Good food.
2. Using the muscles as in games and drill exercises.

What is "good" food, and why ?—We know now that it must contain certain things the body needs, *i.e.* carbon, able to be oxidised in the body. But will all substances be sure to be good foods, because they can be oxidised by the body ? If you drank some of this methylated spirit would it be oxidised in the body ?—Probably some of it would. It contains the same bodies as fat, of which carbon is one, and as you know it burns or oxidises very easily in the lamp, so we might expect it to oxidise in the body too. But it takes time, doesn't it, to oxidise any substance, and before all the spirit was thus broken up it would do you harm, poison you. A pint would probably kill you. Methylated spirit is almost all (90 per cent) a liquid which is called *alcohol,* and it is this which burns or is oxidised,

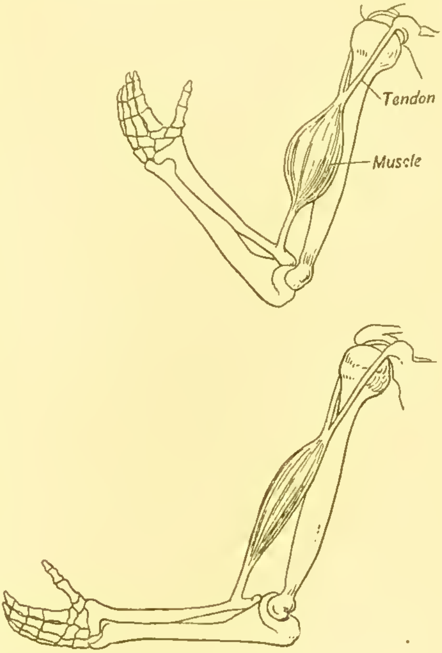


FIG. 18.—Biceps muscle.

and it is also this which before it was oxidised would hurt certain parts of the body.

Here is a true story, which shows how only a very little alcohol spoils muscle action in dogs.

There were four puppies, and two were given a very little alcohol with their food, and two were only given water. The alcohol puppies became much quieter and more sleepy. All four had been taught to fetch back balls thrown for them, but of 1400 balls, the water drinkers brought back 922, the alcohol drinkers only 278. They had far less—what ?—Energy, and could do less work. So alcohol, a body that you might have expected to give energy, lessened it. The alcohol dogs were not even getting as much energy out of their other food as the water dogs.

Next lesson we will discuss why these dogs had less energy than the others.

Answer in writing :

How do muscles move limbs ?

Where does the energy come from for the shortening and lengthening of muscle and the work done through movements thus made possible ?

SECTION XII

Aim.—To show that muscle action is controlled by the protoplasm of the brain through the nerve protoplasm, and that it was the action of alcohol on this protoplasm which was primarily responsible for the laziness of the puppies.

Requirements.—Fresh rabbit's or sheep's brain. Fig. 19 of protoplasmic molecule. Fig. 20 of brain, nerve, muscle.

In the last lesson we learnt that puppies which drank a little alcohol every day were not so healthy as water drinkers. How did they show this ?—They did not fetch balls nearly so well. What part of their bodies seemed specially to be hurt by the alcohol ?—The parts chiefly concerned in movement—the muscles. At first the muscles were probably not much hurt, but as time went on and they were not used, they must have got "flabby." What does this mean ?—Usually, if healthy, a muscle is like a bit of stretched elastic, all ready to begin to shorten.

If it is flabby it will take longer for it to shorten, for it has, as it were, to be tuned up first a little bit tighter, like a violin string.

But from the very beginning, the dogs who had alcohol were less active than the others, though at first their actual muscles were probably not enough hurt by the alcohol to account for the difference in their powers of movement. They were more sleepy from the first ; they did not want to fetch the balls. What part of your body is it that thinks about things and *wants* to do things ?—Brain.

What is brain ?—It consists chiefly of the most important substance in the world—a substance found in all living things, the living part of them—protoplasm, the life substance itself. This protoplasm is in all parts of your body. Suggest a few of these parts to me ?—Muscle, blood. What is protoplasm like ?—We can only see it if we make it look very much larger by using the lens, as in a microscope. It seems then to be a colourless jelly-like substance with tiny grains of food material in it. What chemical substances would you expect it to be chiefly made of ? Would you expect to find lead or zinc forming part of it ?—No. It chiefly consists of the same things as we find in food materials, *e.g.* carbon, oxygen, and some other very important substances we shall find in foods later on. Protoplasm is always changing, always taking up into each of its molecules more molecules containing carbons, oxygens, etc., and giving up others. Because it is alive it has this power to change and break down the foods and use them.

Just now we want to think of brain, which is chiefly made up of this wonderful protoplasm.

Here is a picture of the human brain, taken out of its hard protecting brain case, what we call the head or skull, and here I have a rabbit's brain just to show you how very, very soft and delicate a thing it is. Of course you are not looking at protoplasm itself, but at different substances which have been made by it from the food this animal supplied to it.

What do we do with our brains ?—We think; decide what to do.

We don't know how protoplasm gives us this power of thinking and willing, but we know that we can't think well if the protoplasm is not supplied with proper food. (See back.) It also breaks up some food (molecules) and makes some of them join with oxygen, and what will be produced then ?—Energy. Perhaps it is this energy that is used for thought. Would you expect that protoplasm would somehow have to help in the union of oxygen and, say, carbon of food in the brain ?

Remember what happened when iron and oxygen joined in the cold. What had to be present ?—Water.

What help did we give to copper oxide and fat before the fat and copper oxide were broken up and the oxygen joined with the carbon of fat ?—Heat from a flame. Help of some kind was necessary, and in the brain, protoplasm gives that help. So protoplasm has a great deal to do and needs to be alive and healthy.

Imagine a protoplasm molecule made up of hundreds of carbons, oxygens, and other substances, to which we will give the letters N, S, P, with hundreds of arms stretching out and taking to itself more molecules of different substances, perhaps a carbon from one fat molecule, and the oxygen from elsewhere, and joining them together and sending them off as carbon dioxide gas.

Why does protoplasm thus need to oxidise food ?—Because energy is required among other things for thought and will. What three things then must be present in brain for good thought ?

1. Right food.
2. Oxygen.
3. Healthy protoplasm.

(*N.B.*—Food and oxygen discussed later. The protoplasm molecule always contains carbon, hydrogen, oxygen, nitrogen, phosphorous, and sulphur.)

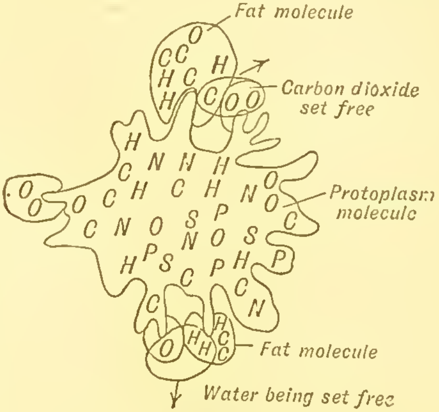


FIG. 19.—Schematic representation of protoplasm molecule.

If for any reason the protoplasm can't do this work of breaking down energy, giving molecules of material, and using part of them to join with oxygen, what will happen to your thinking and willing power ?—It will be much lessened, for there will be less energy. When you are asleep the protoplasm of the brain is much less active, it rests, but then, you don't want to think or work.

When people have teeth out, what does the dentist give them ?—Gas ; and they become unconscious, not able to think and will, also they don't feel pain ; this is because the gas gets to the protoplasm of the brain and poisons the protoplasm—so that it can no longer work properly, no longer seizes on the food molecules and breaks them up, and so, as no such changes go on, there is no energy given out. In time, if too much gas was given, the person would die, which means the protoplasm would die and lose for ever the power to do its work. This is the way people get killed who leave gas turned on but not alight in bedroom.

Now let us go back to our puppies who had alcohol with their food. What did I tell you it made them?—Sleepy. They didn't want to do anything. Why, do you think?—The alcohol they had taken went to the brain cells, just as gas does when the dentist gives it and in the same way as the food. There it partly poisoned the protoplasm, which couldn't do its work of setting free energy from the food, and those puppies couldn't think about fetching the balls, much less want to do so.

But there is still another point in this question of how puppies come to fetch balls. Think of a water-drinking puppy. He sees the ball thrown. His brain is healthy and working, and he *wants* to fetch it. How does the message from the brain protoplasm get to the muscles which have to move before he can do what he wants. Here is a picture to explain:

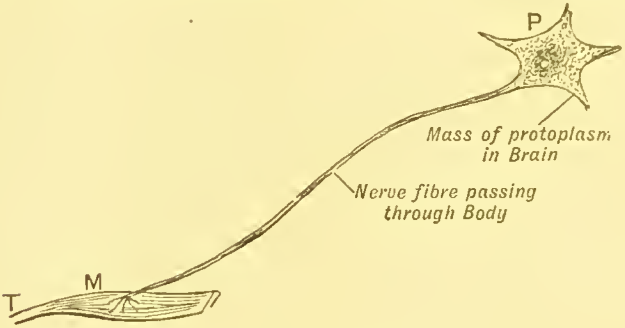


FIG. 20.

P represents a little mass of protoplasm in the brain. M is the muscle of a rabbit's hind-leg with tendon T from "bone." These two are joined by a regular path of protoplasm through the body to the muscle. Such a path we call a nerve-fibre, and every muscle receives such nerve-fibres leading from the protoplasm of the brain. When there is a special desire to do something, some change occurs in the brain protoplasm, and that causes further change in the protoplasm of the nerve path, which acts as a message to the muscle to shorten or lengthen in order to get the movement required. If the nerve coming to a certain muscle is cut in an accident, that muscle no longer lengthens or shortens. The alcohol drinking puppy can't work because of the alcohol ; the puppy's protoplasm is deadened, the right changes don't occur in it, and no changes pass down the nerve path to the muscle, which gets no message and does not lengthen or shorten.

(Go back to rabbit's leg and look at nerve (a collection of nerve-fibres) lying between extensor and flexor muscles.)

SECTION XIII

Aim.—To show presence of alcohol in ale and so explain why certain ale-drinking bricklayers worked more slowly than their teetotal fellows.

Requirements.—Muscle. Nerve (Fig. 20). Small flask (200 c.c. or one-third pint capacity) corked, with glass tube about 16 in. long passing just through the cork. Spirit-lamp. Ale (one-third of a pint). Methylated spirit.

In the last lesson we discussed why a little alcohol made puppies sleepy and not anxious to fetch balls. Every one write down why. Alcohol, it is thought, can be oxidised in the body, and what should we expect it to give ?—Energy.

But what does it do to the protoplasm of the brain ?—It poisons it. What things lead away from the protoplasm of brain ?—Nerve-fibres or paths of protoplasm. Where do they go ?—To all the muscles. What passes down them ?—Some change through the protoplasm. What does this do to muscle ?—It acts as a message to muscles which change accordingly, and show it by lengthening or shortening. What does this pull ?—Tendons which pull bones. What does alcohol do to brain protoplasm ?—Poisons it so that changes in it don't take place, and no message is sent down to the muscles, and movement does not take place. So though alcohol can perhaps be oxidised in the body it was not a good food for the puppies, because it poisoned their brain life-substance. Every one make for themselves a picture like the one I made for you last time, to show you how healthy protoplasm is always working. Use following letters : C, H, O, N, S, P.

Here is another story about men, not puppies, to-day. (See also *Board of Education Syllabus*, p. 13 (*c*).)

Some men were making bricks. Some drank a glass or two of beer with their food, some were water drinkers. By calculating it was found that on the average each water drinker made 795,400 bricks a year, each beer drinker made 760,269 bricks a year.

Every one write down which made the most, and how many. Also the best workman among the teetotal men made 10,000 more in the year than the best beer drinker.

Can you suggest any reason why beer should thus make one set of men think and move—for it is chiefly movements that are concerned in brick-making—so much slower than another set who had no beer but drank water instead ?

If there was alcohol in beer, would you expect it to slow these men's movements ?—It would act just as with the dogs, it would make the brain protoplasm less active, and so the movements would be slower.

How may we try to find out if there is any alcohol in ale ?—We know that alcohol burns. Will ale burn ?—Try to light a few drops in an evaporating dish. It does not burn; but perhaps there are other things in ale besides alcohol, and they may stop it from burning. I mix in this evaporating dish seven teaspoonfuls of water with half one of alcohol or methylated spirit and try to light it. Will it burn ?—No. Can we drive the alcohol out of the water and burn it, if it comes away alone ? Should you expect water or alcohol to come away first from a mixture of the two ? Does the one become a vapour quicker than the other ?

(Drop a spot of alcohol on one child's hand and a similar drop of water on another child's hand.) Which drop goes away quickest ?

Meanwhile here in this flask ($\frac{1}{4}$ full of the mixture) I have water and methylated spirit (or alcohol) in proportion of 14 to 1; the flask is corked and a hollow glass tube 16 in. long is passed just through the cork (with 15 in. projecting into air above). What do you think that is for ?—If the alcohol comes off first it will pass up the tube into the air. What can we do to prove to ourselves that it is coming off ?—Set light to it. I heat gently and every few seconds put a lighted match to the end of the tube. After a time, as the liquid begins to boil, the vapour coming from the tube lights. Notice time. (Only heat enough to keep alight; don't overheat or the water will rush up the tube.)

After a time the liquid in flask boils faster and the vapour issuing no longer lights. (Note time; how long has the flame lasted ?) What do you now see ?—Steam issuing. How can we show it is steam ?—By the (copper sulphate) blue crystal test. What came off first from the mixture ?—Alcohol vapour. Alcohol is a substance that becomes a vapour (evaporates) much quicker than water * [or a little heat energy makes its molecules move out of the liquid mixture much more quickly than the water molecules do]. *

Now we will see if we can find alcohol in ale in the same way. Repeat experiment. Every one draw apparatus while this is done except two pupils who come out and notice how long the flame burns, and if any alcohol comes off. At the end do you notice steam coming off ? What is the result ?—There is about the same amount of alcohol in ale as there was in our mixture, that is, 14 of water and other things to 1 of alcohol.

Now can you tell why ale made the brick-makers who drank it less quick in their movements ?—The alcohol in the ale poisoned their brain protoplasm, fewer messages were sent to the muscles, which made fewer movements, and so less bricks were made.

SECTION XIV

AIM.—To discover if sugar, starch, salt, and white of egg can all pass through animal parchment, and so may be expected to get through the wall of the digestive tube.

REQUIREMENTS.—Diagram of digestive tube (21) enlarged without arteries. 4 squares of animal parchment. 4 small vessels of distilled water. 2 boxes with cardboard lids. Sugar. Starch. Salt. White of egg. Scissors.

We have been thinking about certain foods, and have found that they can be oxidised and that they pass to the muscles and are there oxidised, giving the energy to those muscles so that they can move in shortening and lengthening. Now the question is, How do the foods we eat get from the mouth to—well shall we say the muscle which moves the big toe ?—The food—suppose it is a boiled grain of rice—passes into the digestive tube, which as you see here is a tube. It is centrally placed in your body, but nowhere opens into the body. Then to reach the big toe, what has food got to get through ?—The wall of the digestive tube first. Here I have an animal parchment which was part of the lining of the wall of such a tube. Can such a food as sugar go through this parchment ?

How can we arrange an experiment to try ? Is the wall of the digestive tube dry ?—No, it is in very much the same condition as the thin lining of your mouth and throat, *i.e.* quite moist, and just as you find you can bring liquid into your mouth so liquid is also poured into the digestive tube by cells forming its wall. In what other ways is liquid added to food in digestive tube ?—By drinking. So the digestive tube has liquid in it much of which is *water*. What happens to rice when you put it in your mouth ?—You chew it up and mix it up and moisten it with liquid in your mouth and swallow the moist ball thus formed. So if we want to see if food as we swallow it will pass through the membrane or lining of digestive tube, what ought we to do ?—Mix up the food with water first and soak the parchment in water also.

The *foods* we will try shall be salt, treacle, starch, and white of egg. Can any one suggest how to arrange the experiment so as best to imitate conditions in digestive tube ? — Make the parchment square into a little vessel with four corners, so that the solution can be poured into it, and then arrange the parchment vessel suspended with its base in pure water ; *e.g.* place the water - containing vessels in a box, cut out slits from its lid, and by passing fine string through the corners of the parchment vessels suspend these from strips of the box lid with bases just resting in the water. Really the digestive tube is simply moist on the outside, and has other moist parts of the body packed closely around it. It does not hang in water, as we have put our cups, but we want enough water to test later on.

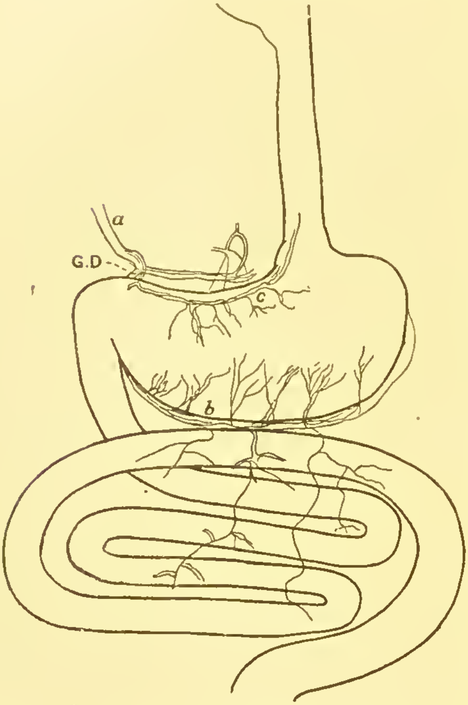


FIG. 21.—Digestive tube showing some arteries.

Arrange 4 such parchment cups resting in distilled water. Pour into " 1 " a strong solution of treacle and water, into " 2 " a mixture of white of egg (half white of egg and half water), and into " 3 " a cooled very thin starch paste made by boiling a saltspoonful of starch in $\frac{3}{4}$-test-tube of water, and into " 4 " some salt solution. Of course be careful that none of the solutions run over into the water vessels, as the object is to discover if starch or white of egg or sugar, as in treacle, or salt can pass through the parchment membrane.

Four children come out and make solutions, and others make parchment cups; rest write description of experiment.

SECTION XV

Aim.—Continuation of Section XIV.

Requirements.—4 parchment cups as arranged in Section XIV. Iodine solution. 2 evaporating dishes. Spirit-lamp. Nitric acid and ammonia (few c.c. of each). Large jar cold water for cooling test-tubes.

Examine the four cups set up in Section XIV.

How can we tell if any sugar has got through the parchment ?—Taste the liquid in jar. Evaporate a little of the liquid from the parchment cup and some of that in the jar. Each becomes sweeter. Why ?—Because the sugar has passed through the parchment. Now see our water is all driven off and we get a black treacly mass. Why ?—Because the sugar molecules are split up by the heat and oxidised and carbon is left.

How can we tell if any *salt* has got through ?—Taste. Evaporate. Here we get actual salt back.

How can we tell if any *starch* has got through ?—Taste. Evaporate. No starch is left from the liquid in outer jar. Why can't we taste it ?—Starch has no taste. Instead of tasting we will do a very pretty test.

Take out the parchment containing the starch, and pour off a few c.c. into test-tube. Add a few drops of this yellow solution of iodine. What colour comes ?—Blue. Starch is the only thing which gives that colour. Now, how shall I find out if any starch has got through the parchment ?—Take some of the liquid from the jar and add iodine. Now you see we get no colour. Therefore, no starch has got through the parchment.

* (We don't know quite certainly why starch can't get through. Some people think that it is because it has such very large molecules made up of so many different parts that

they can't push in between the parchment molecules, while the smaller ones of the salt and sugar can.) *

Why do you think you can taste and smell certain things, *e.g.* salt, sugar, lemon, violets ?—These things dissolve in the liquid in which the lining of your mouth and nose are bathed and then can pass through the lining into the protoplasm or life substance through which you taste and smell.

Can you taste starch if you put it on your tongue ?—No. Starch can't pass through that lining any more than it passes through the parchment.

(*N.B.*—If kept in mouth long it tastes, for it is changed into a slightly sweet sugar. This is dealt with later.)

When dissolved some foods also can easily get through.

What has happened to our *white of egg* ?—The evaporation of the liquid from jar gives no remains of white of egg. White of egg won't pass through lining or membrane of digestive tube apparently. We will use another test to make sure.

I will take a little of the white-of-egg solution from the parchment cup, add a few c.c. strong nitric acid and boil. Note yellow precipitate. Cool. Add a few c.c. ammonia.

Orange colour shows presence of "meaty" (see *Board of Education Syllabus*: "Proteine") food.

Repeat experiment with liquid in which the test-tube of white of egg has been standing.

No change is shown. Therefore no "meaty" food has passed through the parchment.

Children make three columns and write down results they have seen, thus :

Food which passes at once through wall of digestive tube.	Food which will not pass through wall as taken into mouth.	Why I think so.
Sugar (Treacle).	..	Because it passed through the parchment, for evaporation of the liquid outside gave a sweeter liquid which charred as sugar does. It tastes.
Salt.	..	Ditto. But it was recovered unchanged on evaporation. It tastes.
..	Starch.	Because the liquid outside the cup gave no starch on evaporation and no blue colour with iodine as the liquid inside did. It has no taste or smell.
..	White of egg.	Ditto, on evaporation and gave no yellow precipitate with acid and ammonia. It has no taste or smell.

All experiments by scientists confirm what you have been led to expect by above.

SECTION XVI

AIM.—To revise ideas of chemical change in general and of oxidation in particular by preparing and burning hydrogen.

REQUIREMENTS.—Spirits of salt. Granulated zinc. Water. Litmus solution. Evaporating dish. Test-tube with two-holed cork. Delivery-tube. Thistle funnel. 1d. toy balloon. Clip. 2-in. glass delivery-tube drawn out into fine point. 10 test-tubes. 6 bits of clear glass such as microscope slides or clean photographic plates. White powdered copper sulphate.

Last lesson we found that some substances would pass through parchment and some would not.

What passed ?—Sugar and salt.

What did not ?—Starch and white of egg.

Were the sugar and salt changed by being dissolved ?—They were broken up too small * (into molecules) *, and so we could not see them.

What happened when we evaporated sugar solution ?—It got sweeter and sweeter because the water was being driven away and so the solution left stronger.

Why did it char in the end ?—Because at that temperature sugar is oxidised. * (*i.e.* The molecule itself breaks up and some of the carbon can get no oxygen to join with, and is left behind as a black mass.) *

What happened to the salt solution when heated ?—The salt was left behind unchanged.

* (Why ?—Because at the temperature we can reach with spirit-lamp, salt molecules are *not* broken up.) *

When substances dissolve in water, most of them are not changed or their molecules broken up, or altered so that they cannot be got back by evaporating off the water.

Now we will try to dissolve this zinc in water. *H* come out and try. Do you expect it to dissolve ?

Let the child have a piece of zinc in 5 c.c. water in a test-tube. Heat. Filter. Evaporate. Have you ever seen any vessel made of zinc ?—Baths. Also iron roofs are often covered with zinc and called " galvanised." Why are they thus covered ?—To prevent air oxidising or " rusting " the iron. If zinc dissolved in water could we use it for baths and covering roofs which will be out in rain ?—No. So we are not surprised that zinc does not dissolve in water.

Here I have another liquid. Is it water ?

Pour a few c.c. spirits of salt into evaporating dish, add twenty times as much water. Let four children dip tip of finger in and taste and describe what it is like. Why *can* you taste it ? (See previous lesson.)

Pour a few drops into a test-tube and add litmus solution.

What does the colour remind you of ?—That given by carbon dioxide in water, only much pinker.

Everything that makes litmus pink we call an *acid.* So we sometimes call carbon dioxide, carbonic acid gas. Now you see why we had to make sure always that it was really carbonic acid gas we had got by passing it into lime-water. If it only turned litmus pink it might have been this acid or even vinegar. (Add some vinegar to litmus solution and show it. It, too, turns litmus pinkish.) So carbon dioxide gas, this acid I now show you called spirits of salt, vinegar, lemon juice, and many others are all *acids.* Will this spirits of salt dissolve the zinc ?

Ten children come out and each fetch a test-tube containing a few small pieces of rough " granulated " zinc.

Why should we use rough zinc and not thick smooth pieces like that our baths are made of ?—The roughness gives a larger surface for the acid to attack. (Then one child goes round and adds a few c.c. of the acid solution to each of the ten test-tubes.) Every one watch, and then write exactly what they saw. The first finished read out account. Has any one noticed anything else ?—The zinc dissolves. Gas is given off and bubbles through the liquid; test-tube gets warm (collect ten test-tubes).

Person giving best account come out to help do next experiment.

What is the gas given off ?—It might be carbonic acid gas. How shall we test it ?—Pass it into lime-water.

(*For teacher.* Arrange as follows: Seven or eight pieces of zinc just covered with water in tube T. Thistle funnel F (with end dipping below liquid) and delivery-tube D passed through cork. Delivery-tube dipping into lime-water.)

Pour strong acid down F. What will the first gas driven out be?—Air; so leave for two or three minutes, and if necessary pour more acid down F. But the lime-water is unchanged. Therefore the gas is not carbon dioxide gas. It is called hydrogen, and it is used to fill balloons because it is very light. Will this gas burn? Does carbon dioxide gas burn?—No. It is actually found when coal burns or we breathe, and we know it does not catch fire in the air around us.

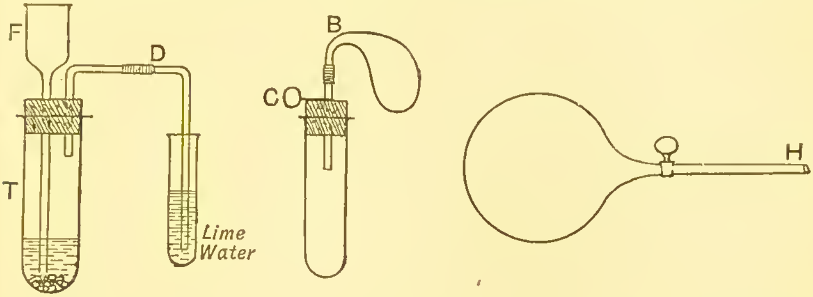


FIG. 22.

(*N.B.*—Don't apply light to end of delivery-tube, or we may have a bad explosion.)

(*For teacher.* Instead of delivery-tube push into cork of test-tube a straight tube with a collapsed penny toy balloon B. Pour acid into test-tube, and only when first rush is over push in the cork, thus making certain that tube is full of hydrogen. If sufficient acid has been added the balloon will slowly distend, filling with hydrogen. Pass the clip up and clip the balloon, removing it at once from the tube to which it is attached, or the pressure will blow out the cork or smash the test-tube. Now we have our balloon of hydrogen gas.)

I push in this glass tube, H, drawn out to a fine point, of course still keeping the clip closed.

Now I want to burn the hydrogen. What shall I do?—Open the clip and gently press the balloon, holding the tip of glass tube in a spirit-lamp flame. What happens ?—The hydrogen lights at once and burns with a yellow flame.

(*N.B.—To teacher.* This colour is really due to sodium from the glass, for hydrogen flame is colourless; but no need to trouble the children with this now.)

While I keep the clip open and there is any gas in the balloon the flame is steady, and by a little pressure on the balloon I can get a bigger one.

Watch what happens when I hold this flame for a second or two against a clear glass plate. The plate is dimmed. Perhaps water is formed. If I hold the flame too long in one place what will happen to this water ?—It will be evaporated off and vanish. The same thing happens if I hold flame against a warm glass surface. Use a cold glass and then the water formed condenses on it. How could you show it *is* water ?—Drop white copper sulphate dust on the damp plate. Now children, describe the experiment to show that hydrogen gas forms water when it burns. The five who do it best shall have a balloon each next lesson, and collect and burn the hydrogen.

(*N.B.*—The colder the glass plate on which the flame is played the better, as only a very minute trace of water is obtained. Powder the copper sulphate, and to see blue tinge produced in it turn the glass over and view through it.)

SECTION XVII

Aim.—To emphasise the idea that oxidation is a source of energy.

Requirements.—Same as for Section XVI., only 5 balloons wanted, also carbon, copper oxide. Bits of glass. Magnesium ribbon.

The five children who wrote the best accounts last time can come early and fill their balloons. (If they can also be allowed to draw out their own glass tubes and get everything ready for themselves before the lesson, so much the better.) If five clips are not available, the ordinary buttons sold with the balloons must be pushed in while the balloon is kept pinched a little higher up with the finger and thumb.

(If this has to be done *in* the lesson, let the other children draw the apparatus used, etc.) When the five balloons are filled, let each child do an experiment with the hydrogen flame to show something about it; *e.g.*:

1*st Child.*—Let the flame play on a cold clear glass surface and show that water is being formed which is evaporated off by *heat* of the flame.

2*nd Child.*—Let the flame play on some carbon on the upturned bottom of an evaporating dish.

What do you see?—The carbon gets red-hot and burns. Will an ordinary spirit-lamp flame make carbon red-hot at once?—Hold a little carbon in mouth of bit of glass tube in spirit-lamp flame. Therefore *hydrogen in burning to form water gives out great heat,* more than spirit when *it* burns gives out.

3*rd Child.*—Direct her flame on a bit of magnesium ribbon. Let another child hold a match flame to a similar piece of magnesium ribbon. Again we see *hydrogen* flame, being hotter, causes magnesium ribbon to burst into flame at once.

4*th Child.*—Mix up together as much copper oxide and carbon as will lie on a penny ; spread on a piece of glass and let hydrogen flame play on the mixture. What happens ?—Some of the mixture turns reddish. Why ?—The oxygen has been stolen from the copper oxide and the copper is left alone.

How much heat did we want when we did this experiment before ?—Heat of spirit-lamp flame when blowpipe was used.

5*th Child.*—Again show formation of water.

Children write.

What do all the five experiments we have just done tell us about hydrogen when it burns ?—"When hydrogen burns it forms water and at the same time gives out a large amount of heat."

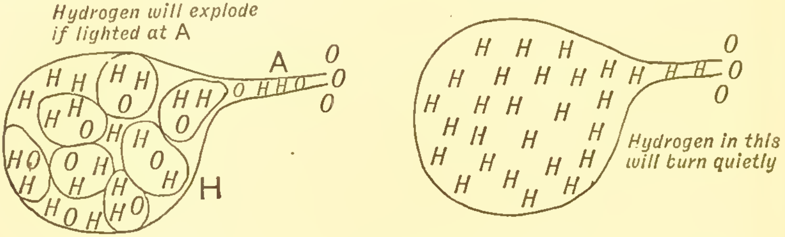

Hydrogen will explode if lighted at A
A
H
Hydrogen in this will burn quietly

FIG. 23

What does it mean when something "burns" in air ?—It joins with oxygen—is oxidised.

When magnesium joined with oxygen what did we call the white powder formed ?—Magnesium oxide. So now when hydrogen joins with oxygen what shall we call the *water* which is formed ?—Hydrogen oxide.

On Board : Hydrogen oxidises into hydrogen oxide or water, and gives out much heat in doing so.

* (What did we say heat was ?—A form of energy. Why ?—Because it really causes quicker movement of molecules, so when we make hydrogen burn we get a supply of *energy* from it, in the form of heat.) *

When hydrogen is *mixed* with oxygen and a light is applied a big explosion is the result.

Why should a *mixture* of hydrogen and oxygen thus explode when the hydrogen coming out from a small jet burns quietly ?

If we have a balloon with a *mixture* of hydrogen and oxygen inside and raise the temperature by bringing a light to the mouth, the particles of hydrogen and oxygen at the opening unite, their flame lights the next, and in a second *all* the hydrogen unites with all the oxygen and forms what ?—Water.

What is given out besides?—Great heat. * (What does this do to the water ?—Makes the molecules move very quickly apart from each other, forming water vapour. These molecules rushing in great numbers against the side of the vessel or the balloon, burst it, and there is your explosion due to the energy given out by the oxidising hydrogen.) *

What happens when you have a balloon full of pure hydrogen and bring a light to its mouth ?—Only the hydrogen at the mouth burns. Why ?—It alone has oxygen. Hydrogen all has to come to the mouth to get oxygen, and water vapour formed there can of course get away easily into surrounding air. Hydrogen explosion is a good example of the energy which oxidation of hydrogen produces. There is as much energy set free when this balloon full of hydrogen burns quietly at the mouth as when it all burns at once and so explodes. The energy given out only depends on the *amount* of hydrogen oxidised, not on the time it takes to oxidise it. How do we get heat energy for warming ourselves ?—By oxidising coal or carbon. What oxide is formed then ?—Carbon dioxide gas.

If we oxidise or burn coal quickly what sort of fire do we have ?—A very hot one.

If we burn more slowly we have less heat from our fire at any one moment, but it lasts longer. Amount of heat energy actually given out from a scuttle of coals is the same whether it takes one hour or twenty-four hours to burn it.

Summary.—Whenever carbon or hydrogen is oxidised much energy is given out, as shown when a quantity of hydrogen is oxidised quickly, by the explosion which follows.

SECTION XVIII

AIM.—To get some idea of the protoplasmic cell as the builder of the body.

REQUIREMENTS.—Rabbit's leg, as used in Section XI. Pennyworth of yeast. Fig. 20 from Section XII. Fig. 24, yeast cell. Fig. 25, gelatine models. Fig. 26, brain cell. Fig. 27, muscle cell. Fig. 28, tendon fibres.

Last lesson we burnt a gas, what is it called ?—Hydrogen. When it burns, what does it do ?—Joins with oxygen and forms water.

What happens if you mix oxygen and hydrogen together and set light to the mixture ?—Explosion. Why ?—The oxygen and hydrogen in joining give out much energy * (*i.e.* the molecules of water formed move very quickly, and in hurrying away burst the vessel in which they are contained). *

Is as much energy given out if you make the hydrogen join *slowly* with oxygen as at the fine-drawn-out point ?—Just as much in the long run if you burn up all the hydrogen. What is made when hydrogen burns ?—Water. When else have you made water ?—When we oxidised suet ; when the candle fat burned. So what must there have been in the suet and candle fat ?—Hydrogen. Starchy foods also contain hydrogen but already joined with oxygen. As we eat fatty foods we eat bodies containing hydrogen.

What else do we know is in the fat and starch molecule ?—Carbon. Why ?—Both char when there is not enough oxygen present ; they give off carbonic acid gas when heated with *plenty* of oxygen.

What happens to the hydrogen ?—That will also oxidise and form water. What is given out when hydrogen is oxidised ?—Energy. How is energy used up in the body ?—To warm the body, to warm liquids, etc., taken into the body, and it is needed for movement.

What kind of movement ?—Of muscles. What else is oxidised in the body and supplies energy ?—The carbon of the foods. As there is more unoxidised carbon than hydrogen in our food it supplies even more energy than the hydrogen. When we want to oxidise foods *outside* the body, what do we do ?—We raise their temperature to a certain point, and we mix them with some body like copper oxide which will at that temperature give up oxygen to them.

How are these foods oxidised in the body ? First, what about the temperature ?—It is much lower than that of a spirit-lamp flame, or we should char away just as meat or bone does in flame. Where does the oxygen come from ?—We breathe in air containing oxygen, it is true, but we know the foods don't join with the oxygen of the air at ordinary temperatures. How can the body get the oxygen of the air to join with and oxidise the food at the temperature of the body ? (Refer to Section XII.) We want to find out what the body is made of to answer this question at all. What would you say is the great difference between your body and the carbon, hydrogen, oxygen, and other things of which we now know it is made up ?—It is *alive*. All animals and plants differ from the rest of the world in this, that they are alive and can take certain not-alive things out of that world and use them and change them, building some of them up into their own living substance or breaking some of them down and using the energy so obtained for movement. But the human body has so many different parts, each with different uses, that it is better in order to understand what being " alive " means to take one of the simplest living things, and that is what I have here. (Slab of yeast.) What is it ?—" Yeast." (If necessary explain how yeast is used in making bread.) Had you ever thought yeast was " alive " before ? It is though. If I take this little crumb of yeast and break it up into the finest possible parts you can see and add a drop of water to still further separate the parts, and then look at it under the lens of a microscope (which makes it look much bigger than this hand-lens does), each separate part is a living thing, which, like all living things, can use not-living things as food. What does one of those tiny living yeasts look like ?

Each is so small that 3000 of them placed side by side would just stretch across a length of one inch. Here is a picture of one very much enlarged. If I measure with this ruler I find it is 5 inches across. How much bigger is it than the real yeast ?—15,000 times bigger. How many real yeasts could I get into this big picture of one ?—15,000. And here is a model, made in gelatine. We call each of the separate yeasts a cell because each is surrounded by a sort of wall of different material to the colourless jelly-like mass inside. It is this colourless jelly-like mass which is the living part, and we must learn its name again, for every living thing begins life as just such a colourless jelly-like mass of living material, and every living thing in later life contains from one to millions and millions of such living masses or cells. It is the same substance as the living substance in the brain (Section XII.)—protoplasm. The lining of the digestive tube is formed of millions of differently shaped cells, but all alike made of this protoplasm, whose chief duty is to help, as we shall see, in getting the food ready to pass through the digestive tube wall. Your muscles are made up of other long-shaped cells, but all containing living protoplasm, part of the duty of which is to oxidise the food when it reaches them. What other duty have these muscle cells ?—To lengthen and to shorten. In your brain are millions of cells, as we said, all made up of living protoplasm, by means of which you think and will to act.

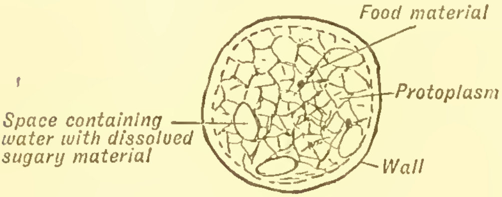


FIG. 24.—Yeast cell.

I told you that every animal began life as a single mass of protoplasm, which we call a cell. How does that single cell give rise to the body, with its brain, bone, muscle, etc. ?—It grows. Yes, and you can see that in the body of any animal, such as an insect or a cat or a bird, the protoplasm is not now one connected mass, as it is in the first cell, but that many different substances, *e.g.* muscle, fat, bone, hair, are present. How have they been made ?

(*To teacher.*—To make cell models run the warm gelatine solution into greased paper moulds, pill boxes or anything box-shaped. Cut out when set and stick two or four of same size together by moistening one side of each with a little methylated spirit and pressing together.)

Suppose this lump of gelatine represents such a single first cell. The protoplasm grows, and when it reaches a certain size it divides and forms two cells still connected together. Next these two divide, giving 4 cells together, and so the cells go on dividing regularly till perhaps there are 32 or 64, all much the same size and shape, rather rounder than I have been able to make my models, partly because they are closely pressed against one another.

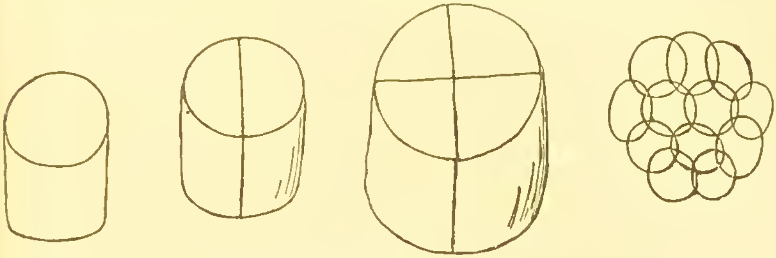


FIG. 25.—Gelatine models.

Then the protoplasm in some of these cells grows more than in others, and divides more rapidly, and the mass becomes very irregular in shape. Some cells grow very long and narrow, and the protoplasm changes on the outside of them, forming a soft sheath of not-living material. These become muscle. Other cells in what has now become the head end of the original mass of cells also divide many times, and their descendants are star-shaped, with one point growing out into a very long arm or fibre. This pushes its way between other cells, and at last forms a bundle with many other similar fibres, and this bundle we call a nerve.

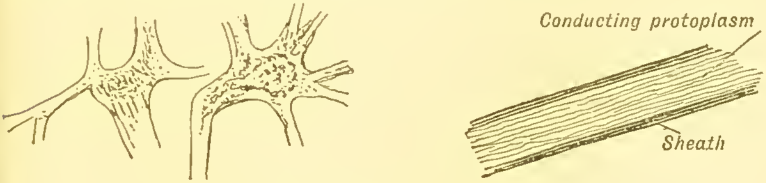


FIG. 26.—Brain cells and part of nerve-fibre.

This diagram (Fig. 20, Section XII.) is one brain cell with one nerve-fibre. How can I represent a whole nerve?—Put in many more cells and fibres all running side by side.

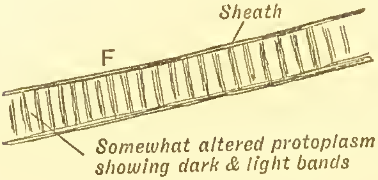


FIG. 27.—Muscle fibre.

Here is the rabbit's leg we looked at in a lesson before. Can one of you come out to show us which is the nerve? The nerve is made up of hundreds of nerve-fibres, each coming from a cell in the brain. The protoplasm inside each cell and in each arm is separated from the protoplasm in the other cells, and their arms by a thin sheath which the protoplasm has built up. There would be thousands of such cells in a piece of brain the size of your thumb nail, but if you looked at the piece through a very very strong lens (high power microscope) you could see that each cell has this distinct boundary.

Here is a picture of still another kind of structure built by cell protoplasm.

Here you have bundles of fine long wavy fibres, unlike the nerve-fibres, for all the protoplasm has gone and only the substance into which it changed itself is there. Here and there are cells of protoplasm.

In its bone, if the rabbit was still growing when killed, you would have found a number of small roundish cells full of protoplasm, separated from each other by the bony substance which its protoplasm had built up around it.

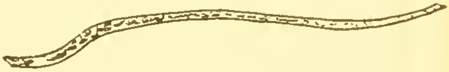


FIG. 28.—Fibre as from a tendon.

But how does protoplasm grow and build up in this way bone and muscle and brain? Whence does it get the material for this building?—From food. Yes, but I want you specially to remember not from starch or sugar or fat, but from certain other foods found in meat, milk, egg, bread, and flour.

Next time we will try and make some yeast cells grow by giving them the right food. Now draw pictures of the different kinds of cells we have talked about.

SECTION XIX

AIM.—To set up experiment for the study of the conditions for the growth of protoplasm in yeast cells, using the quantity of carbonic acid gas evolved as indicating relative activity of growth.

REQUIREMENTS.—3 test-tubes. 3 glass jars (small empty potted meat jars). Dish or jug to hold 2 pints mixture. Treacle. Flour. Yeast (1d. worth). Tepid water. Absolute alcohol. Hand lens. Fig. 29. Budding yeast.

Last time we discussed some of the different cells in the body. What are they all made of ?—Protoplasm. How is the protoplasm of one cell separated from that of the next ?—Usually by material built up by and from protoplasm itself. This time we will do an experiment with some yeast cells. Every one draw (from memory) a yeast cell, please.

If I take a single yeast cell and give it a mixture of the right food, such as treacle and a little flour, what will it do ?—You have together in the healthy protoplasm food and oxygen. The yeast cell will oxidise the food, and may give off carbonic acid gas and water and produce energy. The protoplasm can do what we need the heat of flame for outside the body. Will a yeast cell move and so use up the energy ?—No. Yeast cells, though alive, don't move from place to place ; they are really living plants, not living animals. Their protoplasm is the same, though as the living substance of brain and other body cells. What else will the yeast cell do when you keep it well fed and healthy ?—It will grow.

Look at this picture. It might be a picture of the same yeast cell as the one you have drawn some time after you put it in the treacle and flour. A second yeast cell has grown out from the first, and a third from second forming a chain. What has happened to the food ? Where has fresh extra protoplasm come from ?—Some food has been built up into fresh protoplasm, and after the one cell had grown to a good size a bud was pushed out, as you see, from it. Has any energy been necessary ?—Yes. How have the particles built up been moved from cell 1 to 3, etc ?—By energy.

Where has energy for that come from ?—From oxidation of the food. If sugar, as in treacle, is oxidised, what is formed ?—Carbon dioxide gas. Can we set up an experiment to show that yeast oxidises sugar and forms carbon dioxide gas ? What else might we expect to have formed ?—Water.

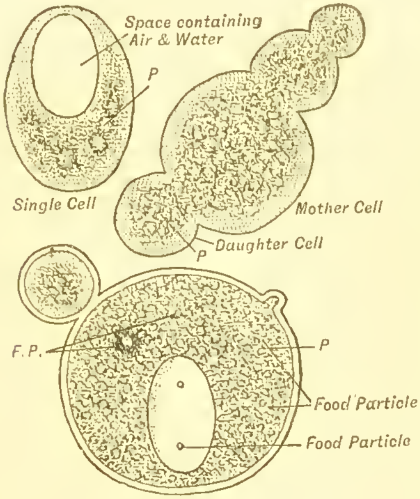


FIG. 29.

Can you suggest the way to do this experiment ?

(After discussion let two children proceed as follows: rest write description.)

Make a mixture of ½ teacupful golden syrup with 2 pints of tepid water, and stir in 2 teaspoonfuls of flour. Fill a test-tube with the mixture, and invert in about 1 inch of same in a glass jar. (Potted meat jars do well.) Stir up a piece of yeast the size of a walnut with a little water and then add to sufficient of the remainder of the treacle mixture to fill three test-tubes. Fill three test-tubes nine-tenths full with this mixture of treacle, flour, yeast, and water. Fill up two of them with pure tepid water and the other with absolute alcohol, shake and invert each into a separate glass jar of flour, treacle, and water, first pushing the tube through a cardboard lid to serve as cover to the jar. Lid of alcohol-containing tube should be vaselined.

Why have we put flour in the mixture, do you think ?—Flour contains a substance which the protoplasm needs for growth. Why have we put alcohol in one tube ?—To see if it will be as useful as water in helping yeast cells to grow.

Let children draw and label as follows :

Treacle.	Treacle.	Treacle.	Treacle.
Flour.	Flour.	Flour.	Flour.
Water.	Water.	Water.	Water.
	Yeast.	Yeast.	Yeast.
		10 per cent alcohol.	
1.	2.	3.	4.

At same time about ¼ fill a 250 c.c. flask with a similar mixture of treacle, flour, water, and yeast, and leave it corked. When we want yeast in dough to " work," where do we leave it ?—Near the fire. It needs a temperature higher than the ordinary room temperature, so we leave our four test-tubes and flask near the stove and appoint two people to watch them between lessons and write down anything that happens. Would any one like to say beforehand what they think will happen ?

(*N.B.*—Temperature should be about 70° F., that is 28·32° C.)

SECTION XX

AIM.—(1) To discover that the waste product alcohol hinders growth in the yeast cells producing it; (2) to set up experiment to discover if unchanged starch will serve as food for yeast.

REQUIREMENTS.—4 test-tubes, etc., as in last experiment. Teaspoon. Vessel for water. Water. Absolute alcohol. Barley grains, some soaked, some well sprouted. Iodine in solution.

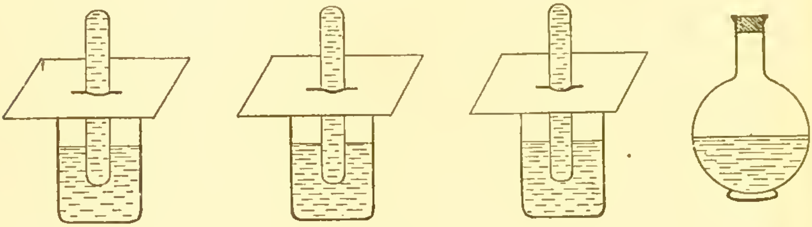


FIG. 30.

Examine the test-tubes set up in the last experiment. What has happened in "1"?—No change. In "2" and "3"?—The test-tube is partly or entirely empty of the mixture, and much frothing is or has been going on. How soon did the frothing begin?—Almost a quarter of an hour after setting it up. What has the yeast been doing?—Growing, using up the food and treacle we gave it. What is the froth and what do you think there is in the apparently empty tube?—Carbon dioxide gas, if the yeast has oxidised any sugar or flour. How shall we test for carbon dioxide gas?—Cork the test-tube under the liquid and lift it out, not keeping the tube open and inverted after removing from the liquid or the gas too will fall out. Turn the tube right side up and put in another cork fitted with delivery tube leading into lime-water. Shake up corked tube till the gas passes over into lime-water.

Into the second empty tube pour a few drops of blue litmus solution, and compare its colour with some unchanged litmus solution. What have we discovered?—Yeast protoplasm oxidises treacle and flour and carbon dioxide gas is formed. (See Sections III. and V.) What use is such energy which comes from such oxidation to the yeast?—It is used up perhaps (in movement of molecules) in growth. Can we discover if there has been any water formed in this oxidation?—No, because we had to mix water with our yeast and treacle mixture to begin with. But I will show you that something else has been formed. Here is the flask in which we left treacle, flour, water, and yeast for one week. Smell the flask; does it remind you of anything?—The yeast has worked and we know carbon dioxide gas has been formed, but that does not smell. What else does give such a smell?

For teacher.—Pour off the liquid without disturbing sediment into another flask of about 200 c.c. capacity, about ¼ filling the flask; push in a cork through which passes a hollow glass tube with fairly thick walls and some 16 in. long. Gently heat base of flask and from time to time apply a light to open end of tube. (See ale experiment, Section XIV.)

When before did we get a gas driven off from a liquid which burnt like this?—From *ale* in Section XIV. With yeast, then, the sugar is only oxidised to carbon dioxide gas and alcohol. (Alcohol itself still contains a good deal of carbon as well as more hydrogen than water.) (Thus starch $= C_2H_{10}O_5$, sugar $= C_6H_{12}O_6$, alcohol $= C_2H_5OH$.)

When yeast is growing under its natural conditions the alcohol made will pass off into the air, and the yeast will not have to live in a solution of alcohol. Would it matter if the yeast had to try and grow in alcohol?—Look at our fourth test-tube. What was in it?—Treacle, flour, water, yeast, 10 per cent alcohol. What has happened?—The yeast has not grown, there is no froth because the yeast protoplasm has died or is dying, and cannot break up the sugar or flour or build it up into itself. The alcohol has poisoned the protoplasm. One scientific man (*Alcohol and Human Body*, chap. iii.) wanted to find out just how little alcohol would hurt the yeast, so he counted the cells, and where 2061 cells had grown without alcohol, only 852 grew in $\frac{1}{10}$th per cent alcohol, and in 5 per cent alcohol only 69. Let a child come out and make up a solution of alcohol of that strength to show how weak it is. One hundred teaspoonfuls water to one-tenth teaspoonful alcohol. Yeast protoplasm makes alcohol in oxidising the food, and yet if only a little alcohol remains in the solution in which yeast is living, it gradually kills the protoplasm. *Alcohol* is a waste product, and has to be quickly got rid of. Just in the same way our protoplasm makes other waste products in the process of oxidation and by its countless other changes, and if we don't get rid of them by the mouth, or skin, or digestive tube, they poison our protoplasm, which does not then work so well, and may even be killed if a great quantity of waste is kept in the body. It is absolutely necessary to get rid of waste every day from the body.

Is the waste product of the yeast any use to us ?—We burn it in our spirit and other lamps. We use it to keep certain things in, such as museum specimens and other things which would go bad in the air, also for dissolving many things. (Recall puppies in Section X. Why were some not so active as others ?) We said then that because alcohol poisoned protoplasm the oxidation changes which produced energy did not go on so well, and as a result muscle movement was less. We have now learnt from the pictures showing us yeast cells after living in treacle and flour that living protoplasm does something else besides get energy from food. What else does it do ?—Builds food into itself and grows. What does alcohol do to yeast-cell protoplasm ?—It stops all growth if 13 parts in 100 are present, hinders growth if only $\frac{1}{10}$th part in 100 are present.

What do you think will happen to brain-cell protoplasm if alcohol reaches it ?—Stop its growth too, or hinder it, depending on the amount of alcohol. It was actually found that in puppies which had drunk alcohol fewer brain cells grew. What will happen to protoplasm of muscle cells if alcohol goes to them ?—The same thing probably. What is the most important work that protoplasm is doing in babies and in you ?—Growing. When the protoplasm has built up fresh food into itself it is then able to make out of itself bone or muscle, or blood, or whatever is needed by the body. If alcohol poisons this living protoplasm then what will happen ?—It won't grow and it won't build up bone and muscle and blood. So what will children be like who take drinks that contain alcohol ?—Shorter and thinner and weaker, less able to move about than children who only eat and drink good food. What is *good* food ?—Anything which protoplasm can—

1. Oxidise, and so produce energy.
2. Build up into itself to make fresh protoplasm, and which does not at the same time itself poison protoplasm and prevent its doing 1 and 2.

Let two children make a list of good and bad things which people eat and drink, which we have talked about so far. Write good in white, bad in red chalk.

Good.
Water.
Starchy, potato, rice, bread ; *sugary*, treacle, honey, sugar ; *fatty*, suet, butter, margarine, lard, dripping.

Bad. Alcohol.

Do you know who makes alcohol ?—Brewers. Do they use yeast ?—Yes. Do they put it to grow in treacle ?—No. They use *sprouting* barley. Not barley seeds before they begin to grow, but the same after the roots have sprouted out. We will do two experiments to see if we can find out why brewers make alcohol by using *sprouted* barley and yeast.

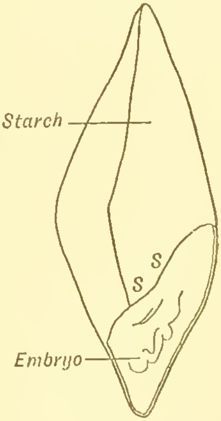


FIG. 31.

First, What is barley made of ? (Diagram of barley.)

Here are some split kernels. What do they look like inside ? The whitish part surrounds the plantlet. Taste them. Not much taste. Could you suggest anything that is like this white tasteless body ?—Starch. If starch were present how could we prove it ? (Use of iodine, Section XVI.) (Scrape the cut side of kernel to break the coats of starch grains.)—Put on a drop of weak iodine solution. What does blue-black colour prove ?—Presence of starch. (*N.B.*—If it does not show well, smash up some kernels, boil in water, cool, and add iodine.) So unsprouted barley contains much starch. Can the yeast use starch for food ? Set up test-tube as in Section XIX. containing ½ teaspoonful starch powder and a small piece of yeast and water. Invert in water and leave. What do you *expect* to happen? (*N.B.*—Don't *heat* starch and water.)

If yeast can use starch for food what will happen by next lesson?—Carbonic acid gas will be formed and there will be frothing.

SECTION XXI

Aim.—(1) By explaining the process used in brewing to introduce the idea of ferment action; (2) to discover that different beverages contain different percentages of alcohol.

Requirements.—Starch and yeast test-tube experiment of last time. 250 c.c. flask corked with 16-in. tube through cork ¼ full of gin. Same quantity of medicated wine and stout. Sprouted and unsprouted barley seeds. Balance. Figs. 31 and 32.

What has happened to the yeast we left to grow in cold starch and water last time ?—Nothing. No carbon dioxide gas formed, so there is no frothing, and the tube is still full of the mixture of starch, yeast, and water. If we could look at this yeast under the microscope would you expect it to be "budding" and growing ?—No. Yeast can't use starch as food. Why not ?—Starch is not soluble in cold water and can't pass through the cell wall of the yeast cell, which resembles parchment paper. (Recall Section XV.) So the protoplasm inside the yeast cell can't get at it.

On Board.—Yeast cells will not oxidise starch ; it cannot get through the cell wall to the protoplasm.

Last time we were discussing how beer is made, and I told you that in the first process, which is "malting," the brewers use sprouting barley and yeast. Let some children taste the sprouting and non-sprouted grain. Is there any difference ? —The sprouted is slightly sweeter. Try iodine test on some sprouted grains. Not so blue as when put on non-sprouted grains. There is less starch now present.

(Let two children counterbalance about 10 seeds against some seedlings of barley so that equal weights of both are taken. Squash up the equal weights thus obtained separately, each with half a test-tube full of water, boil, cool, and add 4 drops iodine solution to each.) Which test-tube shows iodine and starch colour test?—That containing the ungrown seeds.

When grain is kept moist and warm something called a *ferment* in the protoplasm of the cells acts on the insoluble starch and turns it into soluble sugar, which can then pass through the cell walls into the cells of the young growing plantlet. This diagram (Fig. 31 from Section XX.) shows you the plantlet. What is all the material at S?—Starch. Why does the plantlet need the starch?—To give it energy for growth. What is between the plantlet protoplasm and the starch?—Cell walls. What must happen to the starch before it can pass to the protoplasm in cells of plantlet?

When brewers are making beer or spirits they begin by letting barley sprout in this way till the starch begins to turn into sugar. Then they over-heat the grains, enough to stop the plantlet from growing and using up the sugar for itself, but not enough to kill the ferment, so it still goes on turning starch into sugar. This over-heating is called "malting." Next the grains are ground up so as to let the ferment get at all the starch, and it is all converted into *sugar*. Then yeast is added to the sweet liquid. Why do brewers "malt" the grain first?—That the protoplasm of the barley cell may make a ferment which turns starch into sugar, which can pass into yeast protoplasm and can there be oxidised. When yeast oxidises sugar what is formed?—Alcohol and carbon dioxide gas. What will happen to the carbon dioxide gas formed?—It escapes into air, but some is left. Beer owes its "head" to this escaping gas. When is beer "flat"?—When all the *gas* has escaped. What is left then in the liquid after malting and mixing with yeast?—Alcohol and water, and some little sugar and carbon dioxide gas. If the mixture is left in that condition and hops are added, beers of varying strength are formed.

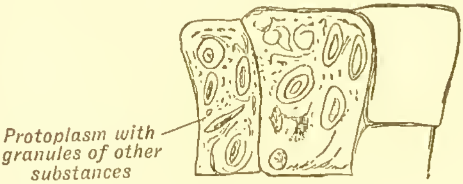


FIG. 32.—Cells containing starch grains.

What would be the strongest beer you could get by this process, *i.e.* beer containing the most alcohol ?—A beer containing 13 per cent alcohol.—Why couldn't you get a stronger beer ?—Because the yeast protoplasm is killed if more alcohol than 13 parts in 100 parts is present. But are there no drinks which contain more alcohol than 13 parts in 100 ?

Here I have a flask containing some gin. How can I find out if this gin contains as much alcohol as ale ?—Repeat experiment of Section XIII., and notice how long alcohol comes off from tube.

We will also try this medicated wine (*e.g.* Wincarnis) and this stout. We must heat exactly the same quantity of each and notice how long each gives off alcohol. Which will contain most alcohol ?—The one that burns strongest and longest. Do experiment while children rule three columns and enter results after describing " How we can find out which drink contains most alcohol."

Drink.	Time taken to drive out all Alcohol.	Percentage of Alcohol given by Teacher.
	Minutes.	Per Cent.
Ale (from Section XIV.) . .	5	4-7
Stout	10	
Wincarnis	20	20
Gin	25	40-50

(Apparently other substances present affect rapidity with which the alcohol is given off, and this is only a very rough test of amounts present.)

(To show the above percentages graphically.)

Here I have four strips of paper of equal length, each divided into 100 equal parts. Four of you can come out and colour certain amount of each strip red.

First strip, 4 parts red. What will red stand for ?—Quantity of alcohol in some ales.

Second strip, 7 parts red = some ales and stout.

Third strip, 20 parts red = Wincarnis.

Fourth strip, 45 parts red = gin, whisky, brandy.

How much alcohol was enough to stop yeast working altogether ?—10 per cent. Just about as much as in claret and wines, about a fourth of that in spirits. What did 5 per cent alcohol do to the yeast in those experiments of which I told you ?—Lessened the number of cells which grew in the solution from 2061 in water to 69 in 5 per cent alcohol.

So alcohol about the strength of ale could nearly stop all growth in yeast cells, and they would not grow at all in as much alcohol as is present in Wincarnis or gin.

SECTION XXII

AIM.—To revise ideas already gained as to the nature of protoplasm by a comparison with starch.

REQUIREMENTS.—Diagrams from Section XVIII. Fig. 34, starch grains. Gelatine model of a cell. Schematic diagram of protoplasm unit (Fig. 19 from Section XII.). Fig. 33, digestive tube cell.

Some one come out and write down on the board the name of the drink which we found had least alcohol in it last time. Class tell the order of the rest of the drinks according to the amount of alcohol. How much is enough to poison protoplasm of puppies' brain cells or of yeast ?—Less than in ale, the one that contains the least alcohol. No child or man can drink alcohol without having his protoplasm partly poisoned, even by very little.

Answer these questions in writing.

What is yeast ?

What does yeast do—(1) to sugar, (2) to starch ?

What does alcohol do to yeast ?

Why does ale contain alcohol ?

Why is ale bad for children ?

What did beer do to the brickmakers ?

If you had to tell any one in six words why alcoholic drinks are bad for the body what would you say ?—" Alcohol even in small quantities poisons protoplasm." What is protoplasm ?—The living substance in the body. Whereabouts in the body is it found ?—Everywhere. In brain, in muscle, inside bone, wherever there is work to do.

(Diagrams of nerve cell, muscle cell, brain cell without names.)

Who can remember what each of these pictures is meant for ?

All these pictures are two or three thousand times larger than the real things, and only show you one slice of the cell, one face of it, remember; the actual cells are solid, like these gelatine models.

In a cell like this other one, which is a picture of one from the inner side of digestive tube wall, besides the colourless half-liquid protoplasm, you may find embedded in the protoplasm globules of fat or grains of other food material, and the water mixed with the protoplasm contains dissolved sugar. How would you say protoplasm differs from, say, a grain of starch?—We know what starch is made up of. If we split it up into smaller and smaller parts we come at last to the molecule of starch containing a definite amount of carbon, hydrogen, and oxygen, and that molecule, while it remains starch, never changes. If millions of exactly alike molecules have been added together you get a grain of starch like this in a cell.

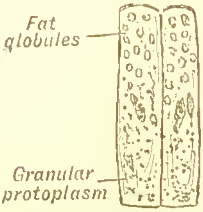


FIG. 33.—Cells from intestine during fat absorption.

Protoplasm is not like starch; we can't talk of a molecule of protoplasm; the smallest speck of protoplasm we can imagine is always changing; it never has a fixed amount of certain substances in it like starch; it is always getting rid of some substances and adding others to itself. Starch can't take bodies different to itself and build them up into itself. Protoplasm can. It can take hold of molecules of sugar and starch and oxygen and oxidise them, and build up other materials, which it gets from such foods as flour and eggs, into itself, making more protoplasm.

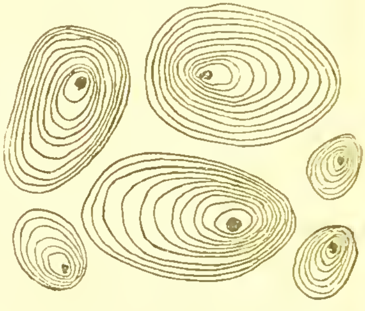


FIG. 34.—Starch grains.

Protoplasm changes and uses substances different to itself for setting free energy and for growth. Starch can only be broken up through something outside itself, such as heat or protoplasm. We can say what protoplasm does, you see, though we can't say what it is. Can you draw a picture to represent protoplasm to yourself as always active, always changing?

Diagram of protoplasm unit with "arms." (Fig. 4, Section

XII.) No one has ever seen, even with the best lens, a protoplasm unit any more than any one has seen a *molecule* of starch, so we don't really know what it looks like. This is only a fancy picture to remind us what protoplasm *does*. Probably it is so easily hurt by poisonous bodies because it does so easily change. It can change easily and make more protoplasm or life substance, but can also change easily in unhealthy ways and be easily poisoned and die.

We want to give it the foods it can use to build up more healthy protoplasm, not the things like alcohol that poison it and stop its right changes.

Answer in writing :

What do you know about starch ?

What do you know about protoplasm ?

Possible answer to questions, " What is yeast ? "

" A bit of yeast is made up of millions of cells sò tiny that we cannot see them. Each cell is a sort of bag with a thin wall inside which is living substance, or protoplasm."

The protoplasm may have in it molecules of food substances dissolved in the water, or sometimes forming masses which can be seen in the protoplasm as little grains. Because the protoplasm is alive it can take out of some of these molecules the carbon, hydrogen, oxygen, and other things that it wants and build them up into itself, and so grow, and it can break down others and make their carbon and hydrogen join with oxygen and so obtain energy.

SECTION XXIII

AIM.—By discussion of its structure to prepare for understanding the effect of alcohol on growth of frog spawn.

REQUIREMENTS.—Frog or toad spawn. 3 pie- or other shallow dishes with vaselined edges and lids. Absolute alcohol. Water. Graduated test-tube. Fig. 35 of frog's egg or any ovum. Fig. 36 of tubercle and erysipelas bacilli. Siphon tube for removing water from pie-dish.

Last time we discussed protoplasm. What do you think this picture is? (Diagram of an egg cell from any animal. Fig. 35.)

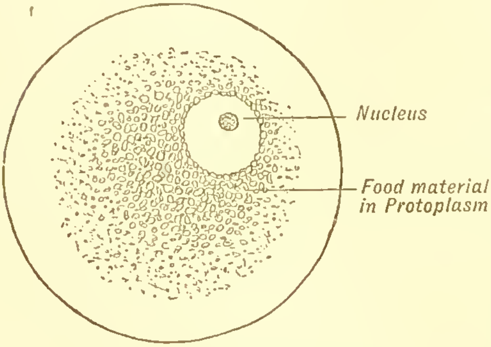


FIG. 35.—Egg cell from any animal.

A single cell of animal protoplasm.

Every single plant and animal starts life as such a single mass of protoplasm. But though some animals remain all their lives just such single cells, most become much less simple; we get animals like chickens, dogs, men, built up of millions of protoplasm cells, and with bones and muscle, and nerves and hair and skin.

How is it a body like that can be built up from just one single cell?—The protoplasm can build up new protoplasm if proper food is given, and can also get the energy it needs from food. So new cells are formed from the first one, and in the end the protoplasm of these cells builds up the bone, muscle, etc., of body.

What is this that I have here in this dish?—Frog spawn.

What is frog spawn ?—Eggs of the frog. What is an " egg " of a frog ?—Just one single cell at first which has grown in the body of the frog and is laid by it in some pool. And this single cell will grow into a tadpole, and the tadpole into a frog, if we arrange to give it certain things. What things ?—A right amount of light, air, heat, water, food. Here is a diagram of such a frog's egg. What is the central part " O " ?—*The actual living protoplasm* containing much food substance which can be built up into new protoplasm, and from which new cells can be formed. What is the surrounding part " F " ?—A layer containing more food material. What for ?—To be used by the growing cells when they have used up all they already contain. This layer can do something else, too. What do you think ?—Protect the all-important egg cell—the living protoplasm. I must draw an outer layer to represent the jelly you see around the spawn. What is this outermost layer of all for ?—Chiefly for protection ; it encloses all the mass of egg cells in a moist, jelly-like mass. These eggs are very often laid near the edge of a shallow pond, so what do you think will be their chief danger ?—Drying up, and this jelly-like covering is the very best way of keeping the living protoplasm from drying up.

We said just now that we must give this living protoplasm certain things if it is to grow and build up the tadpole. Do you think we need give the eggs any food before the tadpoles are hatched ?—No, there are enough food-stores in the egg cell itself until then. But I want to show what happens to these cells of young protoplasm if we put a very little alcohol in the water in which they have to grow. What do you think may happen ? (Remember what happens to young protoplasm in yeast cells.) We shall want to compare what happens to eggs in alcohol and water with what happens to eggs in tap-water. Tell me how to arrange it.

Put 24 eggs in ordinary water and 24 in alcohol and water. Both must be in a shallow dish with only a little water covering the bottom. But if we leave both open, what will happen to the alcohol ?—It will escape (evaporate), and so we shall not know how much alcohol we have in our water. So we will vaseline the edges of the dishes and put glass lids over them. But then will the eggs get enough oxygen ?—They get as much as they want in the open field. We will try and give them enough by draining off the water every second day and filling up with fresh water which has been made to take up as much air as it will by falling from a height. We will always keep the water at same height in both dishes, and add same amount of alcohol to the one dish. How much alcohol shall we add? (Use graduated test-tube to measure.)

We will have three dishes, as follows:—

(1) Twenty-four eggs in tap-water only.

(2) Twenty-four eggs in tap-water 100 parts and alcohol 1 part.

(3) Twenty-four eggs in tap-water 100 parts and alcohol 5 parts.

Let three children come up and get these dishes ready. Shall we have to keep them warm? (Field conditions in February and March don't include warmth of houses.)

What happens to most of the frogs' eggs in the world?—They get eaten by birds. Who eats the birds' eggs?—We do; the food stored up in the yolk and white of an egg for the living protoplasm cell within makes very good food for us.

Can frogs' eggs and birds' eggs feel?—No; so we are not giving them pain either by giving them a poisonous drink like alcohol or by boiling them.

Is it ever right to kill lower living things at all? When?—If harm will come through not taking that life. Do you know any example of a living thing being hurtful to man? What is the cause of consumption?—A living thing which is only one single cell, one mass of protoplasm like this in shape, but so small that millions would go to one inch if placed side by side.

Diphtheria, plague, and many other horrible diseases are caused by just such single-celled living things.

Is it wrong to kill these germs, or microbes, as they are called?—Far from being wrong, it is an absolute duty to help to get them killed in all possible ways. When else is it right to take life?—For food for our bodies. When we cook cabbage, when we eat mutton, millions of living cells have had to be killed. Is there any other reason for taking life?—When it is necessary for food for our minds. If you were to pluck a flower to put in your room, or to examine it to see how it was made, you bring about the death of thousands of cells. If you were to examine the leg of a rabbit to find out how the muscles are arranged, and how they bring about movement, and if you eat the other leg, then you first got food for your mind and then food for your body. So here we are going to give some eggs a

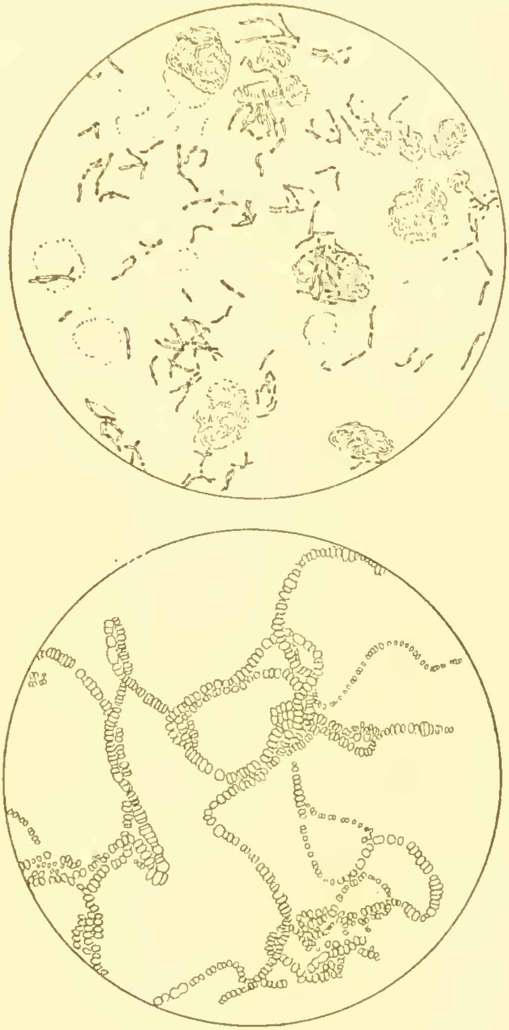


FIG. 36.—Consumption and erysipelas bacilli.

poisonous substance, alcohol, in order that we may learn something. We are not going to give anything pain, and we are not going to waste anything, because we shall use as food for our minds whatever we find out by trying to grow these eggs in alcohol. Suppose I went to the pond where I got these eggs and dragged all the spawn out and left it high and dry, would that be wrong? Why?—Because I wasted life, made it of no use to any one. All the energy and food which had gone to build up those eggs in the body of the frog that laid them would all be wasted. But if I use them and you use them to learn something, or a bird uses them for food, is that wrong? Do you think it would ever be right for you yourselves to take any living thing, even a fly, and kill it and make experiments on it to find out things? Why not?—Because you don't yet know enough ever to take life unless some one older and wiser has said you may. A living thing is so easily hurt. You may so easily waste life, and to do that is sin.

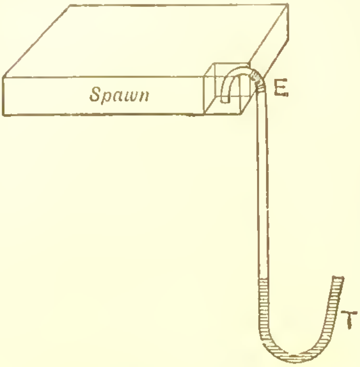


FIG. 37.—Method of drawing off water from spawn.

(*N.B.—To teacher.*—When the eggs in the tap-water begin to hatch have a lesson, and let the children after a silent inspection write down for themselves what differences they observe between 1, 2, and 3.)

SECTION XXIV

AIM.—To discover how to prove that there is a ferment in saliva which, like that in barley, changes starch into sugar.

REQUIREMENTS.—6 grains of rice, equivalent quantity of tapioca, which have soaked for twelve hours. Equivalent quantity flour. Test-tubes. Water. Iodine. Spirit-lamp. Tins which will hold water, *e.g.* golden syrup tins. Centigrade thermometer. Tripod.

Why have we said that rice, tapioca, and flour make good foods ?—Because they contain a large proportion of food which, while it does no harm and poisons nothing, can be oxidised. What is this food ? (Recall tests in Section XV. for starch.)

Let three children come out and hold these three test-tubes on my right hand and another three hold three more on my left hand. Each has got about 1 tablespoonful of water in the test-tube. What else have you got ?—1, 2, and 3 on right have 6 rice grains, a little tapioca, and a little flour; 1, 2, and 3 on my left have same. I had soaked the rice and tapioca for twelve hours before, and so it has swelled. Now the right-hand children are to cook their rice, tapioca, and flour, rest of class write what is done, *i.e.* boil the contents of tube for a minute and cool by plunging test-tube in cold water. (Then face class as before. Teacher passes down line and puts drop of iodine in each of six test-tubes.) What happens ?

Contents of three tubes which have been cooked give a deep blue. Contents of three tubes which were not cooked don't alter colour of iodine. Why does cooked rice go blue ?—Because of the presence of starch. Why doesn't the uncooked starch turn blue ?—Because each starch grain has a sort of coat, and unless that is broken up by boiling in water the iodine cannot get at the starch. What does each starch grain contain ?—Carbon, hydrogen, and oxygen ($C_{10}H_6O_5$). What is set free when this carbon and hydrogen are oxidised ?—Much energy is set free.

Why, then, are these foods we have tested, good ?– Because they contain much starch which can be oxidised. Where is such food oxidised in the body ?—In the cells of muscles, or brain, or wherever energy is needed, either for heat or movement. What must the food get through before it reaches the protoplasm of these cells ?—The walls of the digestive tube cells. When did we test starch to see if it would do this ? (Section XV.) Starch, then, won't pass through cell walls any more than it could pass through the parchment paper. It is not acted on by yeast. How is it, then, that starch can be used as a food ? How does starch come into touch with the protoplasm ?

(This next experiment is to show how the starch is made able to pass through the wall of the digestive tube into the protoplasm.) Let each child put a tiny piece of starch into her mouth and *keep it there,* and not swallow it for as long as she can. Starch, size of small pea. Notice if you taste it at first and if in a minute you notice any taste. Hands up any one who notices any taste.

What does it taste like ? It doesn't taste at all at first, and then gets a little more like what ?—Sugar. (Maltose, the sugar formed, has little taste.) Will sugar pass through the lining of the digestive tube walls ?—Yes. So something in mouth changes starch into sugar. Is starch like sugar at all in what it contains ?—Both contain about the same amounts of carbon, hydrogen, and oxygen, and no very great change is needed. Suppose we want to change starch into sugar outside the body, how might we arrange an experiment ?—I will mix some saliva, or the liquid from mouth, with starch in a test-tube. Does the temperature matter ?—It must be the temperature of the body ($98\frac{1}{2}°$ F. or 38° C.). If I put in a lump of starch, will that do ?—Better mix up a little powdered starch with water, boil it, and then add saliva. Shall I add saliva to the *boiling* starch ?—I must cool it first, for the substance in the saliva which changes the starch is destroyed by a temperature much above that of the body. This substance is a ferment. When else have we had a ferment ?—When starch was changed into sugar by the barley plantlet. The same ferment that acts in the growing barley seed is present in the saliva, or liquid in the mouth. Where is it made ?—In the protoplasm of a special cell. Suppose we have got ready a test-tube of starch and saliva, how shall we keep it at body temperature for long enough to let the ferment act on the starch? Will flame do?—We can't alter it easily enough. We want to put the test-tube in a water bath kept at right temperature, like this (Fig. 38).

Water bath imitates the warm wetness of the living body and blood.

It consists of a tin full of water kept at 38° C. with a lid full of holes to hold the test-tubes and thermometer, and so that these shan't rest on bottom of tin (which, when the light is under tin, gets hotter before water does), a piece of cardboard is pushed down to form a false bottom, this is held by string attached to paper fasteners pushed through the two bent-up ends of the cardboard.

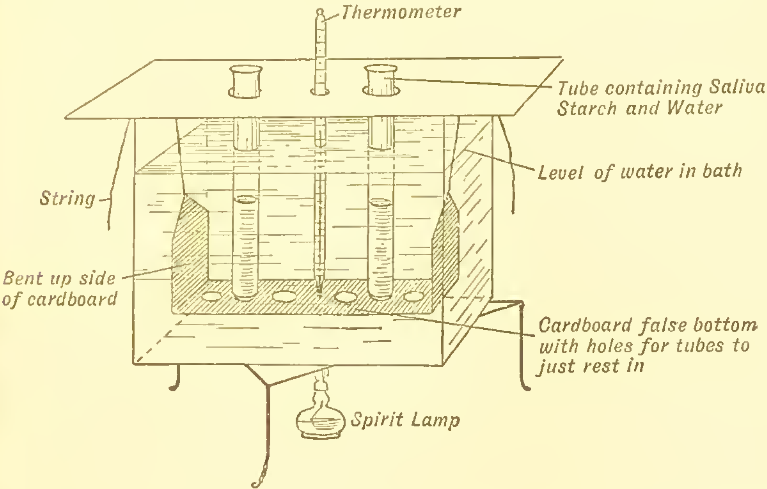

Thermometer
Tube containing Saliva, Starch and Water
Level of water in bath
String
Bent up side of cardboard
Cardboard false bottom with holes for tubes to just rest in
Spirit Lamp

FIG. 38.

Now every one write down, "How we shall arrange a test-tube with starch, water, and saliva to show that saliva acts on starch."

Two experimenters come out meanwhile to make cardboard lid with holes and false bottom for water bath and to powder starch.

(*N.B.*—A heaped salt-spoonful of starch in 200 c.c. ($\frac{1}{4}$th pint) water is the best strength. Just before next lesson collect about an inch depth saliva in test-tube, dilute with 5 times amount of water, filter and put filtrate in two test-tubes.)

SECTION XXV

Aim.—To prove presence of ferment in saliva which will change starch into sugar.

Requirements. — Water bath. Test-tubes. Water. Powdered starch, as in Section XXIV. 200 c.c. flask. 2 test-tubes each ¼th full with dilute filtered saliva. Iodine solution. Fehling solution.

(*N.B.—Saliva* must be faintly alkaline. If it is not when tested with pink litmus paper, which should turn bluish, add a few drops of weak solution of washing-soda.)

Child boils a heaped salt-spoonful of powdered starch in 200 c.c. water. Stand in dish of water to cool. What have I in these two test-tubes ?—Some saliva mixed with water. Why shouldn't we use saliva alone ?—The food doesn't stay long in mouth, only long enough to get thoroughly mixed with saliva, and it is in first twenty minutes that food lies in stomach that saliva acts on it. Other liquids, including any water drunk at the time, will be present and will, of course, dilute the saliva. It is not good to drink much of anything with meals, because of diluting saliva and other similar juices which, we shall see, act on food in digestive tube.

(*N.B.—For teacher.*—In digestion experiments in glass vessels outside the body we need weak solutions, because products of digestion are not removed by absorption.)

To each test-tube of saliva I add same amount of cooled starch solution. Why do we cool the starch ? (Section XVI.) Then I boil contents of one test-tube and put both in water bath, labelling " boiled " and " unboiled." What must be the temperature of the bath ? Every one sketch water bath, two test-tubes, and thermometer, and write down what is in the two test-tubes.

1. Diluted saliva and same quantity of boiled weak starch solution.

2. Diluted saliva and same quantity of boiled weak starch solution, and boiled after adding saliva.

Here I have a third test-tube (3), which I will make up like 1, but not put in water bath.

After ten minutes (may take much less time; ferment in saliva varies in strength) let three children come out, hold each an empty test-tube, to which add about ½ inch from boiled, unboiled, and not-in-water bath test-tubes respectively. To each then add 4 or 5 drops of iodine solution.

1 remains simply iodine colour—no starch present.

2 turns the blue colour of starch and iodine mixed—starch unchanged.

3 turns the blue colour of starch and iodine mixed.

What do you learn from 1 and 3?—Starch is changed by saliva at a temperature of 38° C., not at a temperature as low as that of room. From 1 and 2 boiling destroys the substance which changes starch. How can we show what is left in test-tube 1? I want to prove to you that it is sugar. Here I have some sugar dissolved in water, let some one taste (3 or 4 c.c. treacle in 10 c.c. water; don't use *white* sugar, which won't give test). I add a few drops of this solution (Fehling) and you see a solid form. I boil and it becomes brick-red. Of the substances you are likely to come across only a sugar gives that colour with that solution. Now I add a few drops of the solution to test-tube 1 and boil. Same red solid forms. So what does that show?—Sugar as in treacle now in test-tube 1. Let two children come out, one take a test-tube ½ full of original starch solution, another a test-tube with rest of the solution from test-tube 1. Add to each a few drops of the solution (Fehling) and boil. It proves there is no sugar in starch solution, but there is sugar in the same solution after heating at 38° with saliva. We say the ferment in saliva *digests* starch and changes it into sugar. Why is this necessary?—Because we want our starchy foods, rice, etc., to be so altered that they can pass into the cells, and then through the walls of the cells of the digestive tube into the blood, and so be carried to the different parts of our bodies; and sugar can pass through the walls of the cells of the digestive tube, while starch cannot.

SECTION XXVI

AIM.—To discover presence of a food substance in meat which was not present in starches, sugars, or fats, while showing that meat, like starch and sugar, is oxidisable and yields energy.

REQUIREMENTS.—Diagram of digestive tube (Fig. 39) and of cells from lining of stomach (Fig. 33). Crumbs of meat previously dried as herein described. Copper oxide and apparatus as used in Section VI. Lime-water. Litmus.

(*N.B.*—Get *leanest* meat possible.)

What does saliva do to starch ?—Changes it into soluble sugar.

What makes the saliva, do you think ?—Protoplasm.

This protoplasm is collected in groups of cells, some placed in the floor of the mouth beneath the tongue and others lie in the cheek immediately below and around the lower part of the ear. (This latter group is the parotid gland which swells in mumps.) From each group of cells a very narrow tube leads up to the inner surface of the mouth through muscle and between other cells. The saliva made in the cells is poured into this tube and so reaches the mouth. From the appearance of saliva, what would you say it chiefly consists of ?—Water. It also contains the ferment which changes starch into sugar. It is not known exactly what a ferment is. Where else did we find a ferment which would change starch into sugar ?—In the barley seed when the plantlet begins to grow. Why is it necessary to cook rice or flour before eating it ?—It breaks the starch grain coats, so that the ferment can get at the starch molecules and change them into sugar.

How quickly does this change happen ?—Very quickly, in a minute, as a rule, some of the starch in the test-tube will have changed into sugar. Do we keep food long enough in the mouth for all the starch, say, in a bit of bread to be changed ?—

No, but it is a good thing to keep it in some time and chew it well, so that the saliva shall be able to get at as much of the food as possible.

Where does the food go next?—Into the first part of digestive tube, which we call the stomach. What is the stomach lined with?—A number of cells which, like all cells, contain protoplasm.

(Diagram 33 from Section XXII.)

What will happen to the sugar which has passed into the stomach?—Some will pass into these cells, but a good deal will pass on into this long narrower tube, the intestine, and will pass into cells lining it, such as these in Fig. 33. Why do the cells of the body need sugar?—Protoplasm can oxidise it and so obtain energy.

Last time we had a picture of the digestive tube it was just an outline. Here I have put in lines (M). They represent muscle fibres. What can such fibres do?

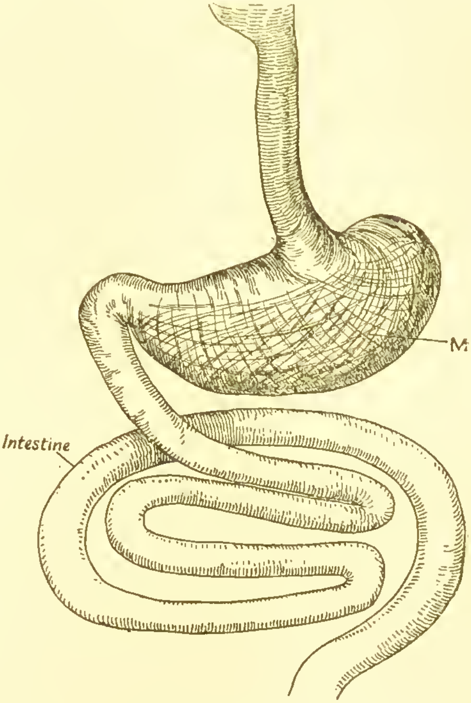


FIG. 39.—Diagram of stomach to show muscle fibres.

Even the stomach itself needs energy for movement, the fibres shown here contract and expand, and in that way the stomach is able to churn up the food, and also push it on to the long intestine tube, where all the dissolved food can be taken up by the cells.

Energy then is needed for movement. Is energy needed for anything else? What did we do with our test-tube containing saliva and starch?—We put it in a water bath at 98·4° F., 38° C. Why is the digestion of starch by saliva best at this temperature?—It is the temperature of the body. What keeps the body supplied with heat energy ?—The oxidation of such foods as sugar. A ferment then has to change starch into sugar so that protoplasm can oxidise it and provide the heat energy necessary if the ferment is to act really quickly on more sugar. Why is the heat that a baby starts life with not enough to keep its temperature up to 98·4° F. ? Suppose the sun shines on snow, what happens ?—The snow melts. If you hold an icicle, what happens ?—It melts. Why ?—Your hand gives up heat to it. If we all go into a cold room, would temperature of room be the same after half an hour ?—No ; we give up heat to it.

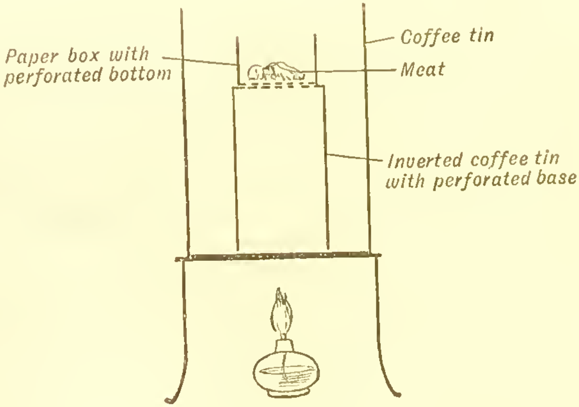

Coffee tin
Paper box with perforated bottom
Meat
Inverted coffee tin with perforated base

FIG. 40.

We "warm-blooded" animals are always giving up heat to things around us. The baby gives up heat this way very quickly, because it has a large surface compared to its size. How do we make up the heat we lose ?—By the oxidation of foods, like sugar and fat. Imagine a child whose cells suddenly stopped making the ferment which changes starch into sugar, and write down what would happen, as far as you can. (None of the starchy food could pass into the cell protoplasm, but would be passed out of the body unchanged, so no heat energy would be got from it.)

What food would you give to such a child ?—Sugary foods or fatty foods, which also are oxidised by protoplasm. Fats also require to be altered by another ferment (lipase) before they will pass through into the protoplasm.

There are other foods that we eat besides starchy foods, sugary foods, and fats. What are some of them ?—Meat, fish, milk, egg.

Do we eat them for the same reason that we eat starchy foods, sugary foods, and fat ?—You don't know; but if we do, what must these "meaty" foods be able to do for us ?—Give us energy. How ?—By being oxidised to carbon dioxide gas and water. How shall we see if this can be done outside the body ?—Heat with copper oxide.

Last lesson I took some very small pieces of juicy meat, about the size of peas, and put them in this paper box, the floor of which I perforated with a pin, as you see. This I then placed on the top of an inverted small tin standing in a larger one, and put the spirit-lamp under the larger one. What happened to the juicy meat ?—It slowly dried.

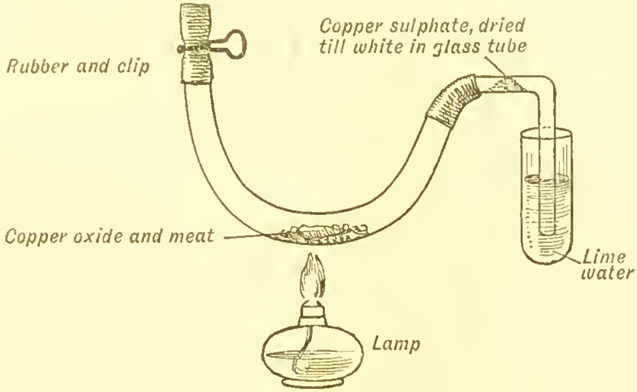


FIG. 41.

(*N.B.*—This takes some hours, and probably some water will be left, but the children will not know.) See, here it is. (Show the dried-up pieces of meat.) What has gone away from it ?—Water. Why did I thus bother to dry the meat ?—Because I want to try to oxidise it and see if I can get water to come off, *as it will do if there is hydrogen in the meat*, and if water is already there, I could not tell if it was that water or the water made by oxidation which coloured my white substance blue.

Now one of you can come out and find out if meat will give off carbon dioxide gas and water when heated with copper oxide. Grind down the copper oxide and dried meat together and put in test-tube, as in starch oxidation.

What did you smell when we oxidised starch or sugar?—There was a smell of burnt sugar.

What happens here?—

1. Lime-water milky, litmus pink.
2. Copper sulphate turned blue.
3. Another smell, not of burning sugar.

What does this tell you?—

1. Carbon dioxide gas given off.
2. Water given off.
3. That there is some new substance here which was not in sugar.

SECTION XXVII

AIM.—To discover presence of nitrogen in white of egg, and discuss its value for building up protoplasm.

REQUIREMENTS.—Raw white of egg. Test-tubes. Litmus paper. Hydrochloric acid. Washing-soda. Flour. Muslin. Diagram (Fig. 35 from Section XXIII.) of ovum. Spirit-lamp.

Last lesson we oxidised some meat and found that something else was present in it which we had not found in the energy foods. This time one of you can oxidise some of this raw white of egg. Let a child take 2 or 3 c.c. of white of egg in a test-tube and heat. The mass blackens. There is the same smell as from meat. What causes the blackening ?—The presence of carbon which is not oxidised. Here are two litmus papers,—paper which has been stained with litmus solution. Here I have a very weak solution of acid (1 drop of HCl to 50 of water). I dip the litmus paper in, what colour does it go ?—Pink. Here I have a solution of washing-soda into which I dip another paper ; it turns blue. What would carbon dioxide gas do to this last paper ?—Turn it pink. Let another girl heat a few c.c. of white of egg in a test-tube while the blue litmus paper is held at the mouth of the tube. There is no change, because the carbon dioxide gas dissolves in the water present. There is little carbon dioxide gas, if any, given off. (*N.B.*—Wash papers in water or the acid may be too strong for the ammonia.) Another child heats a few c.c. but holds pink litmus paper to the mouth of the test-tube. Pink turns blue. Some one else tries starch heated in test-tube. Its fumes do not turn pink litmus blue.

This substance, then, which, like washing-soda turns pink litmus blue, is given off as a gas from meat and egg. Do you think it *is* washing-soda ?—No ; there is no smell from washing-soda, which is not a gas, and does not give off the gas on heating. The gas which comes off from these foods is called *ammonia*. It is also formed in stables, or wherever animal or vegetable waste is rotting. This decay is chiefly due to "germs." A germ is rather like a yeast cell, so what is it?—Just a single cell of protoplasm, but very much smaller. These cells require food and energy, and obtain them by attacking dead or living plants and animals, using them as food (breaking up the molecules of which they are made up much as starch and sugar are broken up in the cells of the body).

One result of this breaking up is that ammonia, a very simple molecule, is formed.

Ammonia (NH_3) contains only nitrogen and hydrogen, so is a much simpler substance than meat. Where have we found nitrogen before?—In air—four-fifths. Does nitrogen in air smell?—No; only when nitrogen and hydrogen join do you get this smell.

When we heat white of egg and get ammonia coming off, where might the nitrogen of the ammonia come from? Air or egg? I can't very easily prove to you that it comes from egg, but it has been shown quite certainly that it does. If we heated the white of egg in pure oxygen we should still be able to get ammonia and other nitrogen-containing molecules given off.

What then are the substances present in meat and egg?—Carbon, hydrogen, oxygen, nitrogen.

Other substances are present, such as sulphur, but for us the important ones are these four. What is their great difference from starch, or sugar, or fat?—They contain nitrogen.

Why do we eat such foods as meat and eggs?—They can give a certain amount of energy by oxidation of the carbon and hydrogen, but we eat them chiefly for the sake of the nitrogen. We take food for the sake of the energy which we get from it. Do we need food for anything else? Think of the single cell from which each living thing starts.

(Diagram of an ovum (Fig. 35) from Section XXIII.)

What has that cell got to do?—Grow. What grows?—Protoplasm. How?—By building up food into itself. But protoplasm must have certain special foods from which to build up new protoplasm, and these are the foods containing nitrogen, as such things as muscle cell, sheaths, and tendon fibres can only be built up if nitrogen is present.

What other foods contain nitrogen? Does flour?—We know that flour contains starch, and starch does not give off ammonia when heated. Is flour all starch? (At beginning of lesson, let a child make a sort of bag of fairly fine muslin, place flour in it, and knead in water, letting the water only reach flour through the muslin, and emptying water away till at last on kneading it hardly shows milky.)

1. Boil some of the water in which flour kneaded; cool, and test with iodine. What does the blue colour show?—Starch.

2. Take some of the sticky mass left in the muslin (gluten, the proteine or nitrogen food in flour) and heat it in a test-tube, testing for ammonia with damp pink litmus paper. Note also blackening of heated mass due to carbon. What do you find?—Ammonia is given off, so there are at least two substances in flour: starch, an energy food, and a nitrogen food which will be used to build up fresh protoplasm. Do animals need new protoplasm once they have stopped growing?—Yes; parts are always wearing out and having to be built up again; the protoplasm itself is always being used up in the process, so that more has to be made. So all your life you need these foods for protoplasm-building purposes. Do you think flour and meat and egg will give any energy?—Yes, for all contain carbon (blacken when heated) and hydrogen (water produced when oxidised with copper oxide), but they do not give as much energy as the foods which only provide the body with carbon, hydrogen, and oxygen. Some one write up on board two lists.

Energy foods contain carbon, hydrogen, oxygen.	Protoplasm-building foods, giving less energy, contain carbon, hydrogen, oxygen, nitrogen, and other substances.
Fatty foods—Butter, lard, margarine, milk. *Sugary foods*—Treacle, sugars, jams. *Starchy foods*—Flour, potatoes.	Meats. Fish. Eggs. Flour. Milk.

Which come in both lists?—Flour *i.e.* bread, and milk.

SECTION XXVIII

AIM.—(1) To discover the necessity for presence of another ferment besides that in saliva which alters starch to sugar; (2) to discuss the effect of alcohol on digestion.

REQUIREMENTS.—Hard-boiled white of egg, cut in small dice, and one or two placed in test-tube. Few c.c. of saliva. Water bath and digestion apparatus of Section XXV. Benger's Liquor Pepticus solution. 2 per cent HCl (hydrochloric acid). Figs. 39 and 42.

Why especially do you eat foods like egg, milk, meat, fish?—Because they contain nitrogen. How do you know?—They give off ammonia, and I told you that contains nitrogen and hydrogen. Why is nitrogen necessary?—Protoplasm can't be made without it. What does protoplasm do in the body?—It builds up all its parts. Name some.—Muscle, bone, blood. Have you ever found any nitrogen in muscle?—Yes, when we heated meat and got ammonia given off. "Meat" is largely the muscle of the animal.

Could you live on starch, sugar, and fat only?—No. Why not?—Because they contain no nitrogen. (Protoplasm has not the power of using the nitrogen in the air.) Which foods contain this absolutely necessary nitrogen?—Meat, fish, bread, egg.

What happens to a bit of white of egg when you eat it?—It gets mixed with the saliva, and passes into stomach. Do you think it can get through into the protoplasm of cells lining the stomach and digestive tube?—(Recall Experiment XV.) The white of egg did not pass through the parchment cup, and as a matter of fact neither can it pass into the protoplasm of those cells. How does starch get through?—It is changed by ferment in the saliva and broken up into the smaller molecules of sugar, which can get through.

How can we find out if saliva will change white of egg as it changes starch ?—Cut out a few small dice from hard-boiled white of egg, place one in a few c.c. of saliva in test-tube, and leave in water bath at 38° C. for ten minutes. Pass the tube round. Children write down if they see any change. White of egg appears quite unchanged. Return to bath and examine at end of lesson. Still unchanged. So saliva will not change white of egg as it does starch. In fact it has no action on any of the nitrogen-containing foods. How then are they made able to pass through into the protoplasm of the cells lining the digestive tube ?

(If Benger's Liquor Pepticus can be obtained, let children do and describe following digestion experiment, but it is rather expensive, and as they have had one instance of digestive action they can perhaps be told about the existence of other ferments acting on the other food substances.)

It has been discovered that just as there are cells which make a ferment acting on starchy food, so there are cells which make *another* ferment which breaks up the big nitrogen food molecule into smaller ones which can pass into the protoplasm of the cells lining the digestive tube. The protoplasm of some of these cells makes this ferment and passes it with water (and a tiny, tiny amount of acid, 2 per cent HCl) into the tube itself, where it breaks up the nitrogen food molecule into smaller ones that are soluble and can pass into the protoplasm.

(*Experiment.*—Here is a liquid which has been taken from the stomach of some such animal as the pig, and here in these two test-tubes I have a small square of hard-boiled white of egg, and in these two some very finely-minced raw meat (enough to spread thinly on a sixpence). Quarter fill all four tubes with water (containing 2 per cent HCl), then add to one meat-tube and one egg-tube 5 drops each of the juice taken from the animal's digestive tube. (Benger's Liquor Pepticus or Glycerole Pepsin.) Where shall we leave the tubes ?—In the water bath at 38° C. Why ?—Because that is just above the temperature inside the digestive tube. We must leave it longer than our starch-digestion experiment, because the food stays much longer in the stomach (1 to 5 hours).

We will start it in this lesson and warm up again in next until we have had it going at least two hours, and then examine the contents of the tubes. We should find at least some of the white of egg and some of the meat has disappeared. Why do we need to put some of each in water only ?—To compare them with those which have been treated with the ferment.

(If experiment not performed, describe it only, and let children draw diagram and name contents of tubes.)

What will happen to the food thus treated and digested ?—Some will pass into the protoplasm of the cells in stomach, most passes on into the long narrower coiled tube which comes next, and all that is soluble is there taken up into cells lining it, and later on we will see what happens to it next. But some food is pushed further on into the narrower tube still not dissolved, and so still other ferments are made and passed into the tube to digest it. We will just add to our diagram (39) of the digestive canal the particular parts where these juices with their ferments are made (Fig. 42). P is a very important collection of cells which produce three ferments, one acting on starchy, one on nitrogen foods, and a third on the third kind of food which has to be made able to pass into the cells. Which food-stuff do you think that is ?—*Fatty* foods. The liver cells also make a very important juice (bile) which helps this digestion of food.

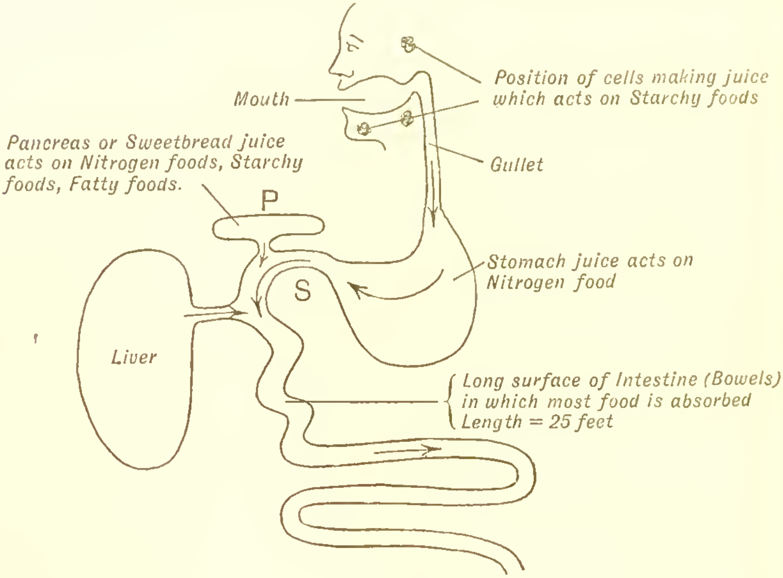

Position of cells making juice which acts on Starchy foods
Mouth
Pancreas or Sweetbread juice acts on Nitrogen foods, Starchy foods, Fatty foods.
Gullet
P
Stomach juice acts on Nitrogen food
S
Liver
Long surface of Intestine (Bowels) in which most food is absorbed Length = 25 feet

FIG. 42.

The making of all these juices to carry out digestion means the spending of much energy by protoplasm, and to do it properly it must be healthy. Alcohol in small quantities seems to cause more of the juices to be made, but yet the extra ferment does not cause a more rapid digestion of any of the foods, because alcohol interferes with the chemical action of the ferment. If you do extra work, and the extra work is of no use to any one, is it worth doing ?—It is a waste of energy. Alcohol has other bad effects on digestion, one of them is its effect on the muscles of the stomach.

(Diagram 39, showing muscle fibres crossing stomach.)

If these muscles running in various directions round stomach-wall contract, what will happen to food inside ?—It will be churned up and well mixed. Also certain muscles run round the narrow end, where the stomach joins the next part of digestive tube (S). If these relax, lengthen, what will happen to S ?—The tube widens, and the food which is ready will be passed on from the stomach to the next part of the digestive tube.

What makes muscle contract and lengthen ?—Messages from the nerve cells of the protoplasm in the brain. In a healthy person these messages arrive continually, and so by movements of the stomach the food is well mixed with the ferment juice and is passed on at the right time.

What does alcohol do to nerve-cell protoplasm ?—Makes it " sleepy " and unable to send such messages, and so churning movements, etc. are not carried on vigorously, and digestion is slowed.

SECTION XXIX

Aim.—(1) Revision of food classification; (2) comparison of milk and stout as foods.

Requirements.—Water bath. Test-tubes. Litmus papers. Copper sulphate, ammonia, and hydrochloric acid (2 per cent). Fehling solution. 2 paper strips divided into 100 parts each on large sheets of squared paper faintly ruled.

Prefatory Note to Teacher on Constitution of a Perfect Food

For a grown-up perfectly healthy person, *i.e.* an adult without disease, in whom all the different constituents of the body are in absolute physiological proportion, one to another, a perfect food would be such material as would exactly maintain that proportion and thus keep that body in equilibrium; for a growing child it would be the same, with due proportionate growth material in addition. A food becomes less and less valuable as it falls below that standard, but it continues to remain a true food, though it may be a very poor one, so long as all that it does do contributes to maintaining the body in health.

But as soon as it contains within itself some substance destructive to or injurious to the body it ceases to belong to the category of true foods and belongs to the poisons.

A good example of an imperfect food is skim milk for a baby; babies so fed get rickets, but not because there is something in the milk which should not be there, but because something is wanting which ought to be there; add the missing fat and it becomes a perfect food. Alcohol, on the other hand, is itself harmful, like all protoplasmic poisons, and no amount of additional material would alter that fact, and it is, therefore, in no sense a true food.

What is the action of saliva on starch and on white of egg?

What is the action of the juice made by the cells lining the stomach on starch and white of egg?

What is the use of the foods being thus "digested"?—They pass into protoplasm. What does protoplasm do with these foods?—It oxidises and obtains energy from them or builds them up into fresh protoplasm. What is built up from the protoplasm?—All the body. Muscle, bone, blood, nerve cells, etc.

Let the children draw rough sketches of the following to illustrate sequence of events.

1. Cell with protoplasm.
2. Cell with protoplasm secreting the ferment containing granules, which may be either saliva or gastric ferment.
3. *Foods*—

Specially energy.	Energy and protoplasm building.	Specially protoplasm building.
A. Starch grain. B. Fat globule. C. Lump of sugar.	1. Glass of milk. 2. Loaf of bread	1. A chop. 2. An egg. 3. A herring.

4. Diagram of protoplasm seizing a molecule of A, B, or C, and oxidising it. Represent latter molecule as containing CH and O only.
5. Diagram of protoplasm seizing molecule of 1, 2, or 3, and building it into itself; represent molecule as containing CHO and N.
6. A child running, or talking, or thinking.

Which are the most expensive foods?—The nitrogen-containing ones; but we must have them, if we are to grow and have healthy protoplasm. It means that we must not waste any money on things that are really not good food. Does alcohol contain any nitrogen?—We can't test it with litmus when we heat it, because it goes away as gaseous alcohol, but when it is burnt, there is no such smell as comes from the nitrogen foods which we have had so far. In fact, alcohol only contains CH and O, so it cannot build up protoplasm. We have put down milk as a food that contains both nitrogen food and the more especially energy-giving food. What does milk chiefly consist of?—It might contain water. How can we find out ?—A child come out and drive water out of blue crystals (of copper sulphate) by heating a few. Place those of the resulting white masses about 2 inches apart on a glass plate. Drop a drop of water on one and a drop of milk on the other. Both turn blue because water is present. Milk contains much water.

Here is a strip of paper divided into 100 parts to represent 100 drops of milk.

Divide off 87 parts by black lines, that shows the water in 100 parts. Here is a flat dish of milk which has "stood" since last night. What is the yellowish mass on top ?—Cream. Which kind of food is cream ?—Fatty, energy-giving.

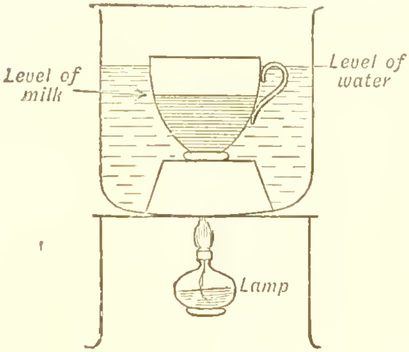


FIG. 43.

Colour 3·7 parts green on paper = fat in 100 parts milk. I skim off the fat. Do you think there is any more food left in skim milk ? Some one come out and boil about 10 drops of the skim milk in the evaporating dish. Boil dry, and say what you notice (others write). As it begins to dry up notice stringy bits in bubbles, at last browns and blackens, and smells. What has happened ?—The water has been driven off, the substance in the milk becomes solid and is finally broken up. There is some carbon left. Some of the substance oxidised. How could we cook milk best without thus "burning" it ?—In a cup, placing the cup inside a water bath ; water to reach above the level of the milk in the cup.

What forms on the surface of the milk ?—A sort of "skin" (coagulated albumen, part of nitrogen food in milk). After milk has bubbled for some time, remove, and leave to cool. (*N.B.*—Formation of "skin" in any quantity may be avoided by *at once* plunging the cup into cold water ; this avoids the usual waste of this part of the nitrogen food in milk.) What is this skin ? After ten minutes remove the skin and wash gently in a saucer to remove any fatty particles. Place some near open end of the test-tube and heat, holding a blue and a pink litmus paper near the mouth.

(*N.B.*—Prepare these litmus papers carefully, so that one is a good blue and the other a good pink, or it is difficult to detect the colour change. Hold one in mouth of ammonia bottle, and dip other in weak (*e.g.* 2 per cent) hydrochloric acid, next washing both in water. Have two of each colour for comparison.)

Pink litmus is turned blue. What does this show the presence of?—Ammonia. What does ammonia contain?—Nitrogen, so milk contains nitrogen food. Blue litmus is turned pink, showing acid body present too. Heating has brought about oxidation and breaking up of this nitrogen food.

So cow's milk also contains nitrogen food (3·5 per cent). What other test have we used for nitrogen food? Recall test for white of egg (Section XV.). To ¼th of a test-tube of milk (meaty or nitrogen food) add 1 c.c. nitric acid, liquid 1. Boil, cool, add a drop or two of liquid 2 (ammonia), the yellow colour turning orange confirms presence of nitrogen food in milk. Test for sugar (with Fehling, Section XXII.). Orange precipitate shows sugar present (=lactose).

Let some one come out and mark the strip divided into 100 parts.

Leave white 87 parts = Water.
,, grey 4 ,, = Nitrogen foods.
,, blue 4 ,, = Sugar, specially useful for energy.
,, green 4 ,, = Fat.
,, black 1 ,, = Other substances (salts).

A grown man doesn't want so much nitrogen food in proportion to the amount of energy food in his food. Do you think a child wants more or less nitrogen food? What is the nitrogen food chiefly used for?—For the growth of protoplasm and building up body parts, so a child wants more of it. Milk is a very good food for young growing children, quite good for grown-ups if they take plenty of other energy foods. Why would milk be a good food for any one after an illness?—Because they want to build up fresh muscle. For what is water specially needed in the body?—To dissolve up all other foods and so make it possible for them to pass into protoplasm. None of the work of the body could be done without water.

Now let us compare milk with another drink some people think is a food—stout. What do you think is in stout?—Alcohol. How much?—Five parts in about 100.

Here is another strip of paper divided into 100 parts. Mark 5 of the parts red, for alcohol. Is alcohol good for protoplasm? It stops its growth if only how much is present? Five per cent almost entirely stopped yeast, 2 per cent hindered tadpoles. So we cannot call the alcohol in stout, food. There is no fat in stout. There may be about ·4 per cent nitrogen food in stout. Therefore, mark ·4 of one of the divisions grey (but in some "oatmeal" stouts there has been found even less, only ·2 per cent nitrogen food). About 2 per cent of sugar is present in some stouts, so mark 2 parts of the strip blue.

Stout strip—

Leave white 89·5 parts = Water.
,, red 5·0 ,, = Alcohol.
,, grey ·4 ,, = Nitrogen food.
,, blue 2·0 ,, = Sugar.
,, black 3·1 ,, = Other substances not foods.

Is there anything specially belonging to the stout which will make up for the poisonous effect of alcohol on protoplasm?—Nothing at all. *Milk has much more of all the foods needed, milk has no poisonous substance in it. Milk is cheaper.*

SECTION XXX

Aim.—(1) To explain the evil effects of long-brewed tea; (2) to sum up work on foods.

Requirements.—Filtered raw white of egg solution (snip white of egg with scissors in all directions, mix with 100 c.c. or 50 times own bulk of water, previously boiled and cooled; filter). Tea. 3 small medicine bottles. Flat dish. Squared paper for children.

Last lesson we compared two drinks, one a good drink, giving energy and building up protoplasm. What was that?—Milk. And the other bad one, what was that?—Stout. Why is stout bad?—Because the alcohol in it poisons the protoplasm and so prevents churning action by the muscles of the stomach. It also causes increased work by protoplasm. How?—Protoplasm makes more digestive juice. Is this any use?—No, because it has been found that there is practically no increase in the digestion of the food even when only as little as two glasses of ale are drunk, and with more alcohol than this, the digestion is actually slowed. This lesson we will compare the action of another drink—tea.

Foods that are particularly affected by tea are the nitrogen-containing foods, so we will take one of those to test. What were they?—Meat, egg, milk, bread. We will choose white of egg, raw (see Ravenhill, p. 420). Let one girl place 3 grams (=2 teaspoonfuls) of tea in a warmed 200 c.c. flask and pour 100 c.c. boiling water over the tea. Wrap up the flask in flannel to keep warm. Have ready 3 vessels (3 small medicine bottles) standing in water bath kept at 38° C. Divide the filtered egg white into 3 equal parts, placing one part in each of the three vessels.

When the tea has infused for 5 minutes pour about 15 c.c. into one of the vessels (*a*) containing the egg white. After the tea has infused for 20 minutes add 15 c.c. of this stronger infusion to a second vessel (*b*), and after 30 minutes 15 c.c. of the still stronger infusion of tea to the third vessel (*c*).

Children make chart as follows :

Vessel (*a*),	30 c.c. egg white solution and	15 c.c.	5 min. tea.
,, (*b*),	30 c.c. ,, ,,	15 c.c.	20 ,,
,, (*c*),	30 c.c. ,, ,,	15 c.c.	30 ,,

After leaving 10 minutes in the water bath examine the vessels for the amount of solid formed.

What is noticed in each case after 10 minutes ?—A little precipitate in the one containing tea brewed for only 5 minutes.

Far more in that to which tea brewed for 30 minutes was added.

This precipitate means that a substance called tannin joins with some of the nitrogen food and makes an insoluble substance. Why should there be more tannin at the end of 30 than at end of 5 minutes ?—It takes time to dissolve the tannin out of the leaves. At end of 5 minutes most of the tannin is still left in the leaves and cannot then act on the nitrogen food. But does it matter if some of the nitrogen food is thus turned into a precipitate ?—An insoluble body like that can't pass to protoplasm, and so will be of no use for building-up processes.

So if we want the tea we drink not to interfere with digestion and the use of the rest of the food, how must we make it ?—Pour fresh boiling water on leaves and pour the liquid off after 5 minutes into another hot pot, or make the tea in a bag and remove. How does tea differ from alcohol in its effect on digestion ?—Tea is harmless if it is properly made, and the hot water with which it is made helps the digestion. The only evil of tea is that when it is badly made it seems to render certain foods indigestible. Alcohol even in small quantities hurts protoplasm. Tea does not contain any real food for the body, but another substance that is in it besides the tannin, appears to make the protoplasm, especially of the brain cells, work more easily, so we call it and it is a " stimulant."

(Children now make charts on squared paper to sum up work on foods.)

Colour	Protoplasm-building food	*Green.*
	Energy food	*Blue.*
	Water	*White.*
	Salts	*Dotted.*

Leave at top of each column numbers of squares to represent prices.

Food.	Per 100 parts approximately.				Relative price in number of squares.
	Protoplasm Food.	Energy Food.	Water.	Salts.	
Beef, 6d. lb . .	20	2	76	1	6
Pork, 6d. lb . .	12	26	61	·05	6
Milk, 3½d. quart .	4	8	87	·6	¾ of square
Margarine . . .	1	84	9	7	4
Cheese, 6d. lb . .	32	31	27	4	6
Eggs, 1=2 oz.=1. .	13	9	65	. .	8
Bread, 1d. lb . .	7	52	40	1	1
Rice, 3d. lb . .	7	80	12	1	3
Herring, ½ lb 1d. .	24	9	53	. .	2
Oatmeal, 2d. lb .	14	73	7	2	2

(See other foods, Ravenhill, p. 282.)

Compare milk and a so-called " milk stout " in same way.

Food.	Per 100 parts approximately.				Relative price in number of squares.
	Protoplasm Food.	Energy Food.	Water.	Salts.	
Milk	4	8	87	·6	¾ of square
Milk stout . . .	1/7	1/4	90	·4	1 square

(*N.B.*—This is taking price of stout to be 5d. a pint—price of milk 3½d. for 2 pints.)

So would need 28 times as much stout to get same amount of nitrogen or protoplasm food from stout as from milk. Cost would be 35 times as great.

SECTION XXXI

Aim.—Revision. Comparison of alcohol with true foods.

What do we need food for?

1. To give us energy. What for?—For heat to keep the body at the right temperature. For anything else?—For movements inside and outside.

2. For building up new protoplasm or life substance. What is the use of protoplasm?—The protoplasm builds up muscles, blood, bone, and makes such things as saliva, and other digestive tube juices containing ferments.

What foods give us energy?—Starchy, sugary, fatty, chiefly; nitrogen foods to certain extent.

Why?—They contain carbon and hydrogen, which can be oxidised.

(*N.B.*—Fatty foods give about double energy, weight for weight, that starchy or nitrogen foods can give.)

What foods can build up protoplasm?—Meat, milk, bread, cheese, egg, fish.

Why?—They contain nitrogen.

Can they give energy?—Yes, for they also contain carbon and hydrogen, but not so much as such purely energy foods, as the fats.

Therefore, on which could you live longest?—Nitrogen foods. Could you live on the purely energy-giving foods?—No. Why?—We must have nitrogen. Why?—For growth, body building. What must happen to all foods before they are of any use to the body?—They must be *digested*. What is digestion?—Making the food soluble. * (Food molecules broken up into smaller molecules so that they can get into the cell protoplasm lining the digestive tube and to other parts of the body where energy or material is needed. By what are molecules thus broken up ?) *

How is food made soluble ?—By ferments in juices, such as saliva from the mouth and digestive tube juice in stomach.

What reasons have you for thinking *alcohol* could be used as a food ?

1. It contains carbon and hydrogen and so can give energy.

2. It is soluble, and passes easily through into the protoplasm of the lining cells of the stomach wall.

Why then don't we use it as a food ?

What is its action on the stomach ?

1. It slows digestion by slowing the churning action of the stomach muscles. Can it be used as a builder of protoplasm ? —No. It contains no nitrogen.

2. It does not quicken digestion when present in the digestive tube juices, and in any amount, *e.g.* more than 2 glasses of 5 per cent beer or 1 glass of brandy, actually slows it. Even in the smallest quantity usually drunk it increases the amount of digestive tube juice without quickening digestion, and so makes the protoplasm work harder than it need and use up energy and material wastefully.

3. It hurts the protoplasm itself, first making it less active, and finally, in any quantity, killing it, as we saw in yeast.

4. It is much more expensive (nearly 30 times) than other energy-giving foods, such as milk. Has alcohol any advantages which the real foods have not got when taken in the right amounts, as you usually have them ?—*Not one.*

Write an essay on : " What I think is the best food, and why."

SECTION XXXII

Aim.—To see how the innumerable blood-vessels act as channels along which digested and absorbed food can be conveyed to all parts of the body.

(*N.B.*—All mention of part played by *lymph* omitted.)

Requirements.—Paper model of arm in layers, enlarged from Fig. 45. Diagram of part of digestive tube with branching capillaries spreading over it (Fig. 21). Fig. 44. Rabbit's leg.

So far we have discussed the kinds of food needed by the body, and how they are prepared or *digested* in the digestive tube ready for the protoplasm, and we have seen that they can, when thus digested, pass into the protoplasm of the lining walls of the digestive tubes.

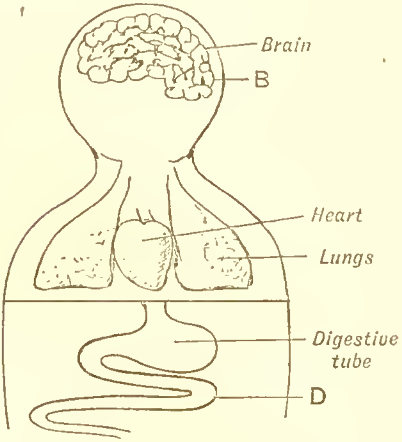


Fig. 44.

Where must the digested food go to be of use?—To all parts of the body. Let us suppose that here at B we have some brain cells needing more food for the growth of their protoplasm or for energy, and here at D you have food just passing through the digestive tube wall.

What is between the digested food at D and the brain cell at B?—Muscle, fat, bone, and all the cells which make up the lungs. What path across and through the body can our digested and dissolved particle follow? Will it just soak through the parts of body between it and the brain? When we want to bring a supply of water to the tap in the kitchen from a tank do we let the water soak through to the tap along any path? How do we bring it?—In tubes or pipes. Has the body any tubes by which the food from the digestive tube can be carried to the different parts of the body? Look at the fronts of your wrists. What do you see?—Dark lines or "veins." What is inside?—Blood. We call such *blood-vessels.* Where else have you got blood-vessels?—Everywhere

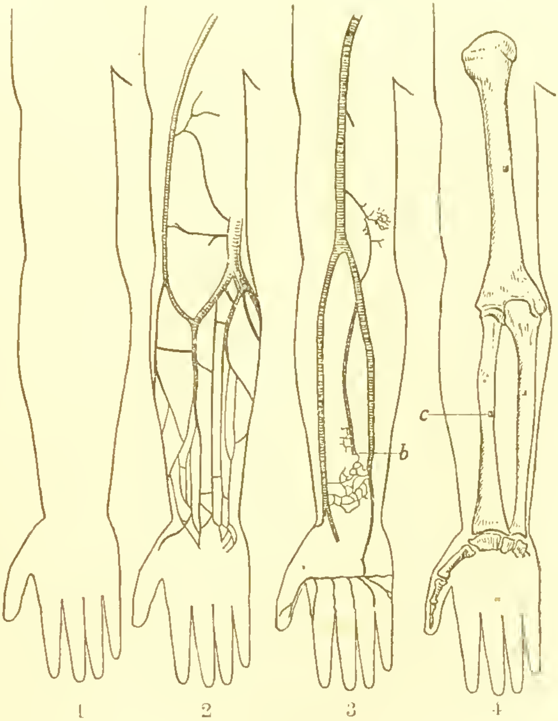


FIG. 15.

in the body. How do you know?—Whenever you prick yourself there is blood, and if you could get at the parts inside the body wall you would find same thing. Now we will make a rough plan of some of the blood-vessels in your right arm.

Here I have a flap of transparent paper cut roughly to the shape of your arm to represent the skin, and you can see showing through the blood-vessels next under the skin.

Now we lift this flap and come to the rather deeper layer

(2). What will it be made of in your arm?—Muscle, and running in and among this muscle are the bluish-red blood-vessels. Can I show all the branches?—No, because some will, of course, go back deeper into the arm, some come up into a higher layer. I can only show some of those which run *along* my slice. Lifting this slice you see this slip (3), which shows a layer just above the bone; here I have marked more blood-vessels, but this time in brighter red, for if you cut down to this layer you would find the blood scarlet and not the bluish-red colour you see it in the vessels near the surface. Layer 4 shows bones themselves. If you went on and lifted out the bone you would find more vessels with scarlet blood further in, and vessels with

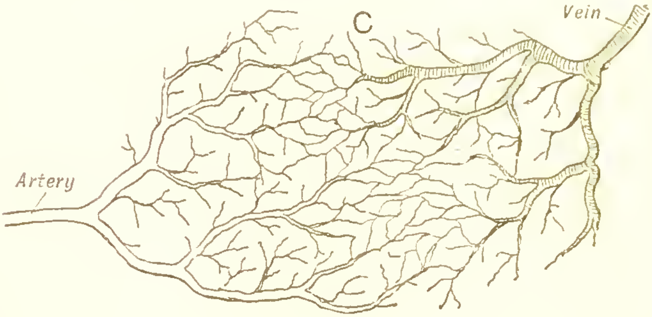


FIG. 46.

bluish-red blood as you pass out, till you reach the skin of the outer side of your arm. I have only shown a few of the main big vessels, every one has many branches, each branching again into smaller and smaller branches like this. Imagine a network of the finest lace with all its threads, made of hollow tubes; if it were 25 times smaller, those you could see would be like these finest branches. These again collect up into larger branches.

How do you know that there must be far more branches than I can draw, that, in fact, there is not a point under your skin where there is not some one of these branches? Prick yourself anywhere and what happens? So fine branches are nearer together than a pin-point.

Examine rabbit's leg used in earlier lesson on muscle. Note again the large blood-vessel running down with the nerve between the extensor and the flexor muscles. This will pass into a network of fine branches spreading over the muscles lower down on the leg and foot.

To what different parts will these blood-vessels go ?—

To the brain protoplasm with which you think.

To the digestive tube, where the food is digested and made soluble.

To the parts (lungs) with which you breathe.

To the muscles with which you move.

What will pass into the blood-stream as the fine branches of the vessels spread over the digestive tube ?

As in this figure, where D is part of the long coiled tube through which the digested food passes when the various ferments have acted upon it, the digested food dissolved in the watery liquid can pass through the digestive tube wall as our salt and sugar passed through into the parchment, and then, also, through the walls of these fine branches of the blood-vessel (A).

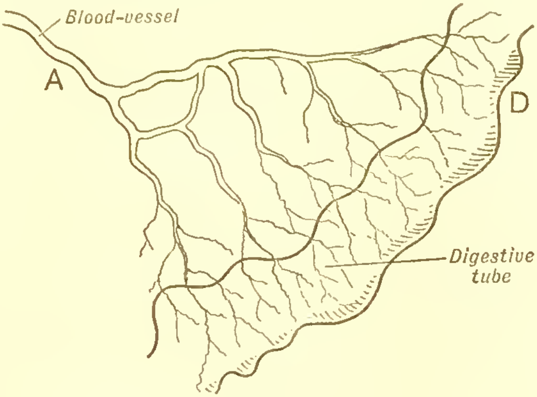


FIG. 47.

The walls of the blood-vessels in these networks are exceedingly thin, so the digested food easily passes through, and is then carried along in the blood-stream to the parts of the body which need the food, when it passes *out* through the thin walls of the fine branches there.

Answer in writing :

How does the food when once it has been digested reach the parts of the body which need it ?

Possible answer at this stage would be:

"Everywhere in the body there are numbers of tubes called blood-vessels running just under the skin, and in the deeper muscle layers, and over the bone, and to, and through all parts all over the body; these vessels, as, for instance, where they run over the digestive tube, break up into very, very fine tubes, each 25 times smaller than the finest lace thread. These tubes have very thin walls. The digested food dissolved in the watery liquid of the digestive tube passes through the digestive tube wall and through the thin wall of the fine branch of the blood-vessel. Once inside, the food material is carried along in the blood-stream to all parts of the body, and when it reaches a part which needs that food, it passes through the thin wall of the fine branches of the tube there."

SECTION XXXIII

Aim.—To study the heart itself as the starting-point of the circulation.

Requirements.—Diagram (Fig. 52) outline of man, showing main blood-vessels in relation to the heart; arteries red, veins blue. Diagrams (49) of front view, (50) of back, of heart, and (51) of a vertical section showing interior, left auricle, and ventricle. 2 or 3 sheeps' hearts with vessels still intact. Glass tubes. Funnel. Blue coloured liquid (*e.g.* ink). 2 pencils pointed, one with red crayon inside, one with blue or black.

Last lesson we looked especially at blood-vessels in the arm. Here is a picture in which you are supposed to be able to see into the body and see more of the blood-vessels. Looking at the arm you see a thickish red-coloured vessel, that breaks up into thin tiny tubes; these connect with tiny blue-coloured tubes, and these join up into a large blue blood-vessel. Where do the big red and blue vessels begin and end?—At this pointed mass in the centre of the chest. What is it?—The heart. Does any one know what the heart is made of or what it does?

Here is a sheep's heart cut away from the blood-vessels and all the blood emptied out, but otherwise exactly as it was in the body. What is all this red, fleshy part?—Muscle. What is the white part?—The fat. What does the muscle do?—Shortens and lengthens. If the heart muscles shorten what will happen? How could I imitate the shortening with this heart?—Squeeze its sides together. What happens?—The liquid inside flows out. Put your hand over your own heart. What do you feel?—A "beat." What do you think it is?—The wall of the heart moving as its muscle shortens, and out as it lengthens. When the wall pushes inwards what happens to the blood inside?—It is forced out into blood-vessels. On this sheep's heart I find four large vessels; will blood pour out of all at once?—If it did you would get two streams, one running along the blue-coloured vessels and another along the red-coloured vessels. Where would they meet?—In the small branches, and then they might stop each other and the blood would stand still. What then would happen to the food?—

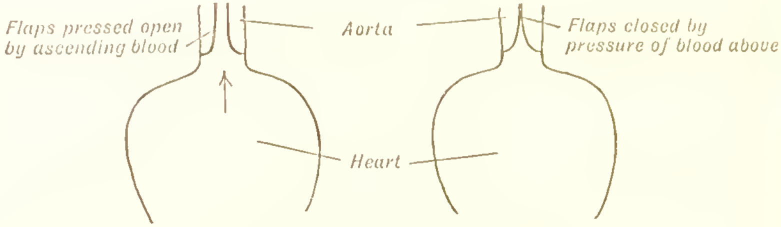

Flaps pressed open by ascending blood
Aorta
Flaps closed by pressure of blood above
Heart

FIG. 48.—Valves open and shut.

It would not get carried to all parts of the body. So for this reason it doesn't seem likely that blood flows *out* of all the vessels at the heart at once. Can any one suggest some way

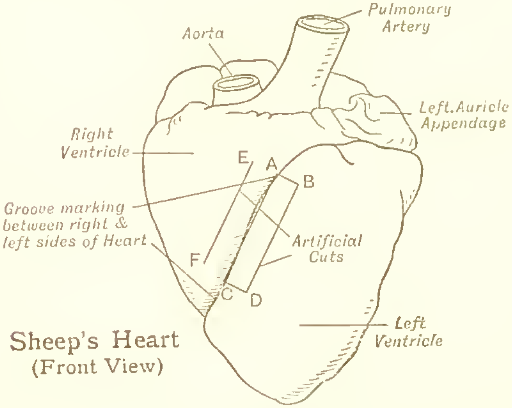


FIG. 49.—Front view of heart showing the front groove, auricles, fat ring, ventricles, aorta, and pulmonary artery.

for the blood to flow so that it would always move and go everywhere?

"If it flowed *out* from some tubes and *in* by the others."

I want you all to come in fives and watch while I pour water into two of these tubes to see where it will come out. When you are not watching I want you to copy the pictures on the board.

With each set of children perform following experiments. Take an intact heart. Point out four large vessels (vena cava, probably with two branches).

What difference is there between these vessels? Two are very thick-walled, white; one (with two branches) very thin, pinkish; one medium thick. Point to aorta in big diagram. "*That* is this middle, thick-walled vessel." Now watch while I pour blue-coloured water into the medium thick vessel. Push the filter-funnel into the pulmonary vein and a fairly wide bore glass tube into aorta, let one child hold the aorta close around its glass tube and another the p.v. edges tightly pressed against funnel's sides. Gently pour blue liquid down funnel, when it should rise up the tube in aorta. Empty out heart, reverse funnel and tube, and again pour down. Liquid rises up in funnel and can hardly be forced out of pulmonary vein. Now look down the thick-walled tube. What do you see?—Three flaps. These are arranged like this. Liquid poured *into* tube only presses them closer together. Rushing out pushes them easily apart.

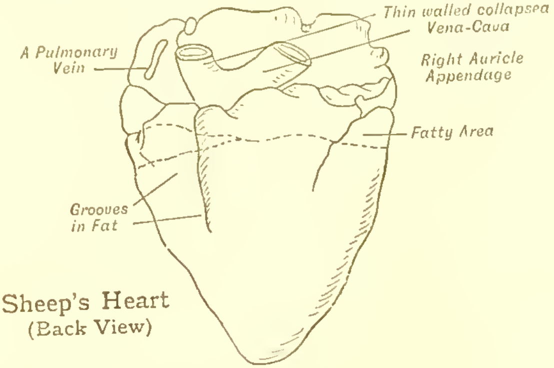


FIG. 50.—Back view showing vena cava and pulmonary vein or their openings into the heart.

Blood then enters heart at a fairly thin-walled tube towards back of heart; leaves by the thick-walled white central tube. We have two other tubes left to try, the thin-walled pinkish tube at back (vena cava) and the thick-walled tube (lung artery) next the other thick-walled tube. One of you arrange our funnel and tube to show at which one the blood enters heart.

(Funnel in vena cava, glass tube in pulmonary or lung artery.) The liquid poured in at thin-walled tube comes out again at thick-walled tube. Does any come out by either of the first two blood-vessels we tried ?—No. What does this suggest ?—Must be at least two rooms in heart with walls between.

(Now show them two hearts, which can be already prepared as described in following.) We will now push these two pencils into the vessels from which water came *out*, *i.e.* the big main artery, red pencil, and the smaller artery, blue pencil, and these two glass rods into the vessels by which we poured water into the heart. Now I will make a cut into the heart wall and show you where those tubes have gone. Obviously if there were only one " room " in heart the water poured into one vessel should run out of any of the other three equally easily. The class ought to be able to foretell at least two spaces with a wall between. To make the cut (see Figs. 49 and 50), place heart with back side downwards, *i.e.* with side which faces to front of body (when in body) upwards. When in this position a groove of fat is visible starting from the middle of ring of fat round thicker part of heart and running centrally down heart for a little way, then bending to *right* side of heart so that it misses the pointed end.

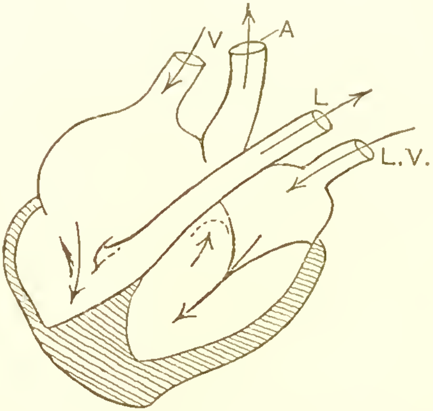


FIG. 51.—Showing four "rooms" of the heart and the vessels entering and leaving each.

A. Aorta.
V. Vena cava, blood brought from all over body.
L. Lung or pulmonary artery.
LV. One of lung veins brings blood back from lung.

N.B.—Wall of left ventricle is much firmer and more muscular than that of right, for it has to pump blood all over body, while right only sends to lungs and back again to heart. With a very sharp penknife cut down the groove as from A to C, and again from B to D (Fig. 49). Turn back the flap ACDB on to the right ventricle. This will give an opening into the left ventricle and should show (1) the wooden red pencil from the aorta protruding into it; (2) (by gently pushing the glass tube placed in pulmonary vein this can be pushed through floor of auricle into left ventricle, and) the two rooms, small above (auricle) and large below (ventricle), shown. (3) Thin flaps between upper and lower rooms of heart. (4) The wall between the two sides of the heart, in position marked by groove and cut.

In a second heart make another cut down EF and AC, laying open right lower room (ventricle). Make children, see—(1) Glass probe from wide thin vessel (vena cava) into which water was poured. (2) Wooden blue pencil from thick-walled vessel (pulmonary artery) from which water came out. (3) Thin lower room wall compared with wall of left room. (4) Wall of partition between right and left sides of heart as before. (5) The thin flaps (with their muscles attaching them to wall of ventricle) which form wall between upper and lower rooms of heart. As you have the two hearts with one side uninjured in each case, water can be poured into vena cava of first and will come out at pulmonary artery, and into pulmonary vein in second case and will come out at aorta; shows again no direct communication between right and left sides of heart.

At end of lesson, when children all back in seats—

Where does the blood-stream start?—At the heart. Why does it move out of the heart?—Because the muscles of the walls shorten, and they press in on the blood, squeezing it out into the vessels with thick walls. Where does the blood-stream end?—Again at heart, brought back by thin-walled blood-vessels.

SECTION XXXIV

Aim.—To revise Section XXXIII. by naming parts of drawings made therein, to connect up the heart with the capillaries, and to emphasise the change which occurs in blood in the capillaries.

Requirements.—Diagrams as in Section XXXIII. on board. Red- and blue-coloured chalks for each child and for board drawing.

From what you saw last time why would you say the heart is a very important part of the body?—It acts as a pump, pumping blood all over the body.

Now I want you to turn to the diagrams you drew last time, and we will put names and explain what each is meant for.

Look at Fig. 49, "Front view of heart." What shall we call all the part that was red and fleshy?—"Muscle wall of heart." What shall we call all white part?—"Fat."

And the middle line which bends to right side of the point of the heart?—"The groove." What is under the groove?—"The wall between the two sides of the heart."

What is on the left side of that wall inside the heart?—Two rooms. Which is the bigger?—The bottom one. Can you tell me anything about its wall?—It is the thickest wall in the heart, double as thick as walls of other rooms. What is this reddish mass with crinkled edges at the top left side of heart?—"Part of the top small left room (left auricle appendage), and the part immediately below it is the fat ring." The wall of the bottom large left room (left ventricle). And this thick-walled tube or blood-vessel arising above or just in fat ring to right of top left room?—A blood-vessel from which blood comes out of the heart. We call the vessels by which blood comes out of the heart *arteries*, so label it "artery." Does any one remember which side of the heart it came from? (Push a probe into the pulmonary artery and show the children you can feel its end in right ventricle.) You see I can feel the end of this pencil in the bottom large right room. So label the blood-vessel "artery from right bottom room." To the right of this artery is another similar but larger white blood-vessel. What shall we call it ?—"Larger artery." Which side of the heart will it bring blood from ?—Left side. (Again push in probe into aorta.) Why do I find it difficult to push a pencil into these two arteries ?—Because they have flaps to prevent blood running back once it has been pushed out of the heart. Well, the pencil is through the flaps now, and I feel its point here. Which room is it in ?—Bottom left room. What sort of walls has that room ?—Very thick. What then shall we label this artery ?—(Aorta.) "Large artery, brings blood from thick-walled left lower room."

Now turn to the third diagram you drew (Fig. 51). What do you think it shows ?—A plan or map of the four rooms of the heart; might represent a very thin slice cut out of middle of heart.

In your third diagram thicken the wall of the lower left room and the walls of the two arteries we have just named in Fig. 51, and put in arrows to show which way blood runs in them.

Turn to your second diagram (Fig. 50). *Back view of heart, i.e.* side which in body is turned towards backbone. Where does this broad, very thin-walled tube (vena cava), rising centrally and behind the two arteries, lead into ? (Push in pencil as before.) I feel the pencil first in this small right hand top room, and then, if I probe around, it goes into the bottom right-hand room.

This is a thin-walled tube. Did water come out of it easily ? —No; when we tried to pour water in at the small artery it simply ran up in our glass funnel and refused to come out at the thin-walled tube. What happened when we poured water into the wide thin-walled tube ?—It gushed out of the artery. The thin-walled tubes take blood *into* the heart, and we call them *veins*. Which is the other vein ?—The tube or blood-vessel at the back just along the left top room into which it opens.

(*N.B.*—There are two lung veins in sheep's heart arising near each other, and four in man.)

Names for Fig. 51, then. "Large vein." "Small vein."

Then in Fig. 51 all of you put in arrows to show which way the blood runs through these veins.

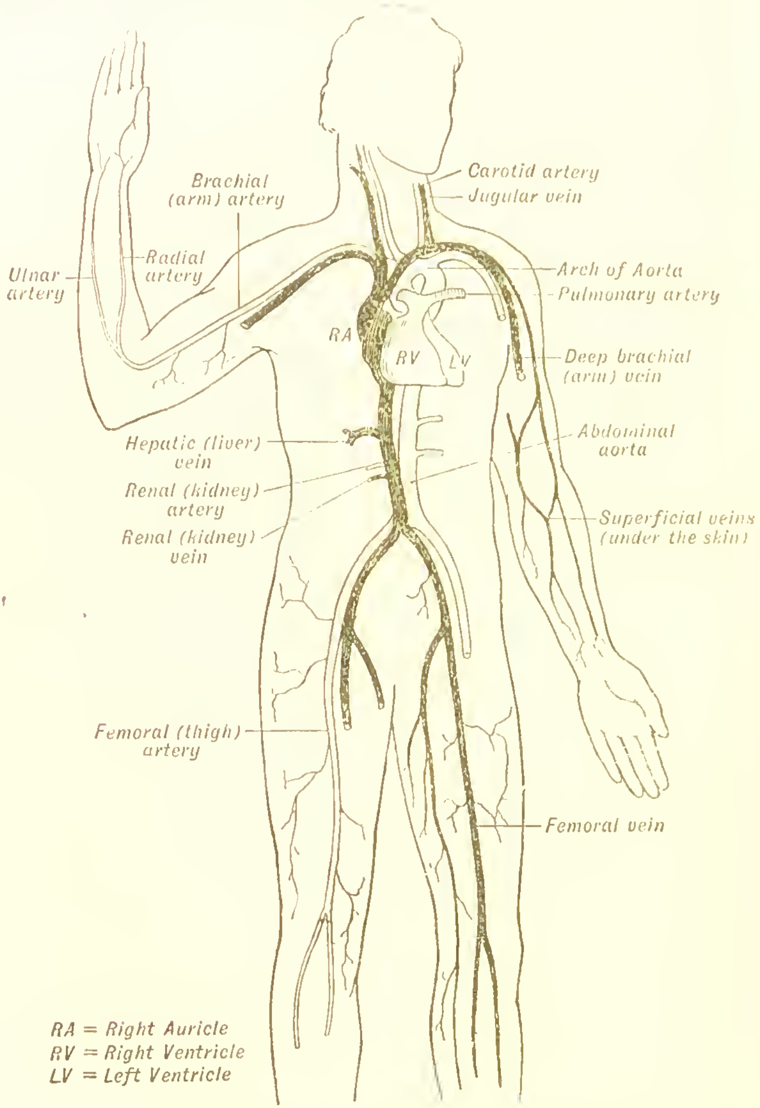


FIG. 52.

So the blood leaves and enters the heart twice; once on each of its sides. Where does it go in between ?—To all parts of body. Also you would see this if you could see the blood leaving the big artery; it would be bright red there, and bluish-red when it entered the big thin-walled vein. So now in Fig. 51 colour the two left-hand rooms, the lung artery, and the small vein, scarlet; and as we haven't a good bluish-red chalk, we will colour the two right-hand rooms, the big vein, and the small artery, blue. Where has the blood been to get its colour changed is the next question we must ask.

I will draw a rough chalk diagram on the board, colouring red those vessels which contain the scarlet blood, and then I will begin to use blue where it changes colour. You must all watch, and the minute I begin with the blue say "blue" altogether.

(Draw a heart as in diagram, colouring the left ventricle, auricle, lung vein, and aorta scarlet. Make aorta branch, red lines running out to represent the two principal arteries in arms; just above these, chalk in two arteries in neck, and continue till some such figure as Fig. 52 is outlined in red on board; but at this stage some of *blue* must be put in. When putting in the arm artery, say, "Where is this artery taking blood to?" and so on for leg and neck. All these arteries branch again and again, and finally run into a network of very fine branches such as we saw in our paper model of the arm. How fine were those branches?—Twenty-five times smaller than the finest thread you could just see (Section XXXII.). Here, on the right arm, I have drawn one such branch breaking up into tiny branches; only, for you to see, I have made the branches 1000 times too large.

(Now pick up blue chalk and start the small veins from the capillaries. Children, if awake, should shout "blue.") Yes, here is one place at which the blood changes its colour and becomes dingy red or bluish-red, among the muscles of the right arm. Where else will it change, do you think?—Muscles of left arm, in legs, and also where it runs into the fine branches over the digestive tube, and in the brain, and in all parts of the body where the arteries branch into the fine tubes the scarlet colour goes. Could it be because the blood takes up food there?—Hardly, for it changes colour just as much in the muscles, bones, etc., where it is giving up food material as in the digestive tube where it is taking in food. The blood, then, changes colour and passes into these tubes, which are branches of wider tubes, and finally runs into tubes, one of which runs along and over each artery; and when we follow it back we find it runs into the heart again through the wide, very thin-walled blood-vessel (vena cava). So I will chalk in blue tubes side by side with the red, all joining the red arteries in very fine branches in the different limbs, and as they spread over digestive tube and all finally coming back through the thin-walled vein to the top right room of the heart. Where will blood go from this top room?—Into the right lower room. The muscle of wall of that room shortens and will push blood out. Will it go back into the vein?—No, because of the flaps we saw across opening, which are pulled closer together by shortening of muscle. Which way will blood go?—By small artery. What colour is the blood in this side of heart?—Its dingy bluish-red, etc., has been changed in body. The blood goes out of the heart, and comes back again changed to scarlet again. Which is the only vessel we have left for it to come back by?—Vein leading into top left room. It comes back by that vein. Next time we will talk about where it goes to change back to scarlet colour.

SECTION XXXIV (*A*)

(May be omitted if points already well grasped.)

Aim.—Revision lesson of parts of heart and the blood-vessels leading to and from it. New part—to discover that the *lungs* are the part in which the blood becomes scarlet again.

Requirements.—Match-boxes brought by each child. Red and blue wool. Labels. Let four girls give round to each child 3 pieces of blue and 3 of red wool, and 3 labels. (Fig. 55.)

Last time we were discussing the heart, and you were all to bring a match-box showing how many separate rooms that heart showed, and what openings into those rooms there were. Now each of you put in red and blue wool in the holes to which you think they belong. Here is my match-box (see end for diagram), and I have made holes and put wool inside to represent the blood-vessels. I have made four rooms in mine. My two top ones are smaller than the two bottom. Have you all got the same ? Then I have a hole here in the floor of each of the small rooms, so any blood in the top rooms can pass through into the ones below. Now hold your box heart against your own heart with the open side towards me. Put your finger over the left large bottom room. Close to the middle wall, high up, I have a hole, and through it passes a blood-vessel which takes scarlet blood away from the heart, so we will put a piece of *red* wool hanging out of that hole.

Again, put the box heart over yours, and your finger on top of the right small upper room here (*i.e.* at B). Here I have a hole, and another just below in the outer side wall of the top small room (at C). Put a piece of *blue* wool through each of these, because these are the big vessels which bring bluish-red blood *back* to the heart. It is the same blood that left by this red vessel we put in, so what must have happened somewhere ?—The red and the blue vessels joined; but they do something else before they join. What? Do they go on as single tubes ?—No, they break up into branches, and these into smaller and smaller branches, just as I showed you in the paper arm model; and then the finest branches of the set coming from the heart run into the finest branches of those going back to the heart like this.

So then it is one big system of tubes with no break.

(There are really two breaks, at the neck and in the spleen, but this is unnecessary for the children.)

The branches when they join are far too tiny to see, finer than the finest hair you can imagine, but the blood can pass along them all right.

Where do you find these networks of fine branches ?—

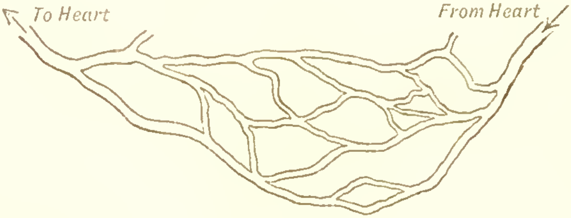


FIG. 53.

Spread over nearly all the organs, over the digestive tube, arms, legs, brain, everywhere. These fine branches have very thin walls. Why ?—So that the food in the blood can pass through to the protoplasm and nourish the arm, or leg, or brain cell. So now we must do something further to our heart box model. What ?—Frazzle out the wool threads to represent branches, and bring the finest ends of both together. We can't connect them as the blood-vessels connect, because we can't manage to join the wool ends together; we can only lay them on one another, and we will stick them together with labels, and write on one label "leg muscle," and another "digestive tube," etc. What do we call blood-vessels going from the heart ?—*Arteries*; and blood-vessels going to it we call—what ?—*Veins*. Show me the artery on your model, and two veins. Where will one branch of the artery go ?—To the digestive tube. What does it do there ?—Breaks up into finer and finer branches. What do these run into ?—Fine branches of a vein, which finally run into the big vein which goes back to the heart. Where will another branch go?—To the arm. What will happen?—It will break up into finer and finer branches in the deeper muscle of the arm. What happens to the finer branches?—They run into the finest branches of a vein, and so back to the heart.

(Similar descriptions of circulatory systems to brain and legs can then be extracted.)

But we have not yet seen how the blood leaving at A and coming back at C and B gets back to A again. We start from right, upper chamber. What has it in its floor?—An opening. So blood passes down into the large right lower chamber, and there is another opening (at D). This takes blood out of heart, so what is it?—An artery. I am going to put *blue* wool leading from it, for blood leaving here is bluish-red still. What will you expect this artery to do?—Break up into fine branches over some part of the body. What will these fine branches run into?—Fine branches of a vein. Which part of the body is this? We have dealt with the parts concerned with feeding and digesting, and with the moving parts and thinking parts. What else do we do besides feeding, moving, thinking?—We breathe. Do you know with which part of your body you breathe?—It is called the lungs. These are two masses of cells, one on each side of the middle line of your chest, by means of which you breathe; and it is to these two lungs that branches from this artery (from D) go. The fine tubes run over the lungs, and meet and join the branches from a vein. Now where do you think the main branch of this vein goes?—Back to the heart. And to which room?—Top left-hand one (at E). So we must put in wool here. I want the wool to be red this time, because this vein brings back scarlet blood.

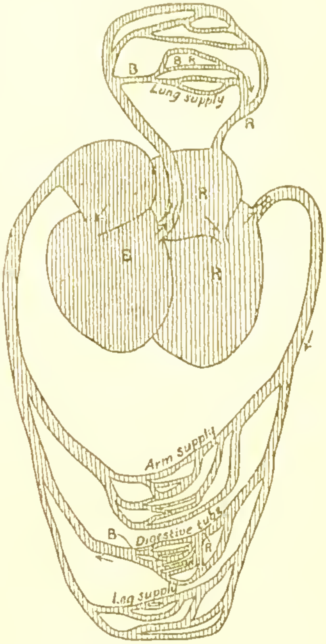


FIG. 54.

Draw diagram put up (54), and colour to show what we have just learnt.

Write this sentence:

"The blood starts out by an artery from the bottom left-hand room, and is scarlet in colour; becomes bluish-red in the networks of the stomach, head, arms, legs; comes back by a vein to the top right-hand room still bluish-red; runs into the bottom right-hand room; passes out, still bluish-red, to the network over the lung; becomes red there; and comes back by a big vein to the top left-hand room, and so into the bottom left-hand room, from which it started."

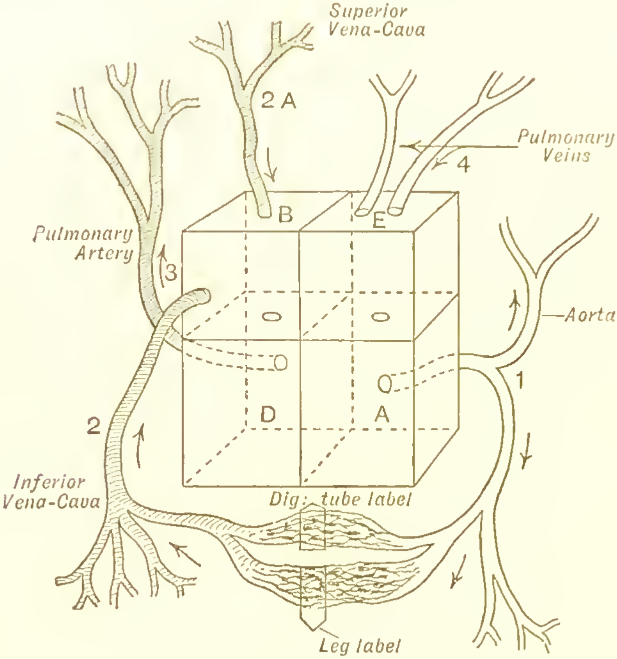


FIG. 55.—Match-box model of heart.

Remember, blood becomes bluish-red in all parts of the body except the lungs.

SECTION XXXV

Aim.—By study of lung construction to discover that blood here meets air, and connect this with colour changes in the blood.

Requirements.—Sheep's lungs with windpipe attached. Bellows. Silk thread.

Tell me something we do with the body, and what is chiefly used in doing it ?—We move (muscle), think (brain), talk (muscle), digest food (digestive tube), etc. There is one thing we do all the time, waking or sleeping, and never think about it. What is that ?—Breathe. What do we breathe with ?—Lungs. Have you ever seen a sheep's lungs ? They are very like those of a man.

Here are such a pair of lungs, and here is a long tube leading down to them, branching into two, one branch going to each big mass. What do you think this long tube is for ?—To take air from the mouth to the lungs. What is it called ?—The windpipe. Cut off a small piece and throw on water. It floats. Why ?—It is full of air—the air we blew into the lung. Does this pinkish mass look as if it were full of air ?—No, it looks just a solid mass. What happens to the large branches of the windpipe when they run into the mass. (Cut out a bit of lung near base of the large branch (bronchus) showing numerous branches, and pass round.) The big branch branches, and these, again, branch again and again, and it is of these branches that the mass of the lung is made up. So if I draw the branches of one branch it would be like B, and this mingling with other branches makes the mass of the lung. Are these branching air-tubes like the blood-vessels ?—Branches don't run into each other, and don't run into another set of tubes. Instead, the end of each tube is swollen. What happens when the air is drawn in down windpipe, do you think ?—Swells out these ends still more, and it is because of the air held in all the branching tubes and their swollen ends that the lung floats. There are so many branches that if the tubes and their ends could all be spread out flat it would cover a surface of 2600 square feet. (Compare some area known to the children.)

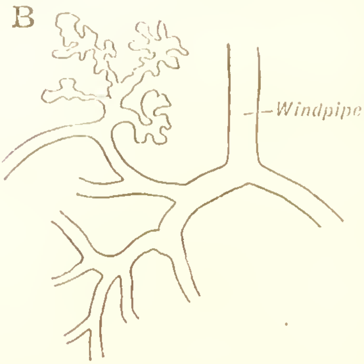


FIG. 56.

Why is the lung pinkish in colour?—Because of the blood there. How is blood brought?—By an artery which branches just as the others branch. Can you see any other tubes besides the air-tubes in the bit of lung given you?—Whitish thick-walled tubes. What are they like?—The arteries we saw on the heart. They are the branches of the small artery we saw coming from heart. What will those branches end in?—Thousands of thin-walled tubes spreading all over the big surface of lung branch. Why then do lungs look pink?—Because we can see the blood through thin walls of blood-vessels as spread over air-tubes. What happens to those thin-walled tubes?—They join with other thin-walled vessels. Can you see any veins in your bit?—Yes, there are tubes with thinner bluish-pink soft walls, and these are the veins. Where will they go?—Into the big vein which runs back into the top left room of the heart. You have got a piece of red wool, a piece of blue wool, and a bit of lung. Draw in your book a heart with four rooms, and put the pieces of red and blue wool leading from it to the bit of lung to show how the blood goes

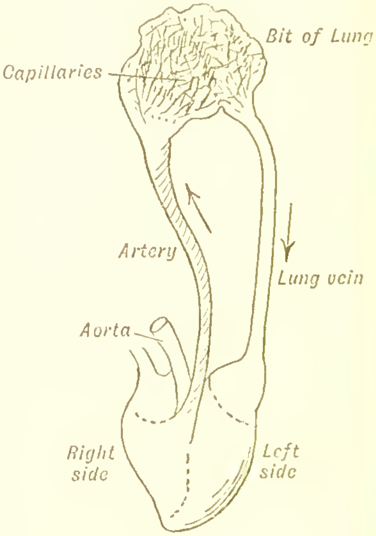


FIG. 57.

from heart to lungs and back, and what happens to its colour.

So the blood in passing over the great big surface of the very thin-walled air-tubes has its colour changed from purplish or bluish-red to scarlet. What can have passed into blood here that doesn't pass into it, say, in the muscle of an arm ?—There are no air-tubes in the arm, or digestive tube, or brain; only in lungs is there air; only in lungs does colour change. Does the air pass into the blood and change it ? What is air ?—Two gases, chiefly. Oxygen and nitrogen; and protoplasm cannot use nitrogen in the lazy state it is in in air.

Are they much alike ?—No. Oxygen joins up pretty readily with other bodies. Nitrogen is "lazy" and won't join up.

Which, then, is most likely to have changed the colour of blood by joining with it ?—Oxygen.

How could we try ?—If we could get some pure oxygen without any nitrogen mixed up with it and shake it up with some purplish blood from a vein. Next lesson I will try and have those two things here, and you shall try.

Now answer question :

"Why do you think that blood may join with oxygen in lungs ?"

SECTION XXXVI

REQUIREMENTS.—(1) Get your butcher to collect blood from a freshly-killed animal in a jar; (2) prepare two jars of oxygen; (3) prepare two jars of carbon dioxide gas (by burning candle in jar till goes out), one containing pieces of blood clot left in it for some hours.

Preparation of Oxygen.—Grind up together equal quantities of manganese dioxide and potassium chlorate; place in a hard glass test-tube, fitted with a one-hole cork through which passes a glass delivery-tube T, the end of which dips under water, and into a glass jar full of water, which was previously inverted into a dish of water, D. On heating the mixture in test-tube the oxygen present in the chlorate will be given off and pass into W, forcing out the water. Allow the first gas driven out of T to escape, as it will be the air previously contained in test-tube. When W is full of oxygen slip a glass plate under its mouth and remove. Leave covered till required. It is better to grease the mouth of W at beginning of experiment with a little vaseline, as glass plate then sticks, and escape of oxygen is prevented.

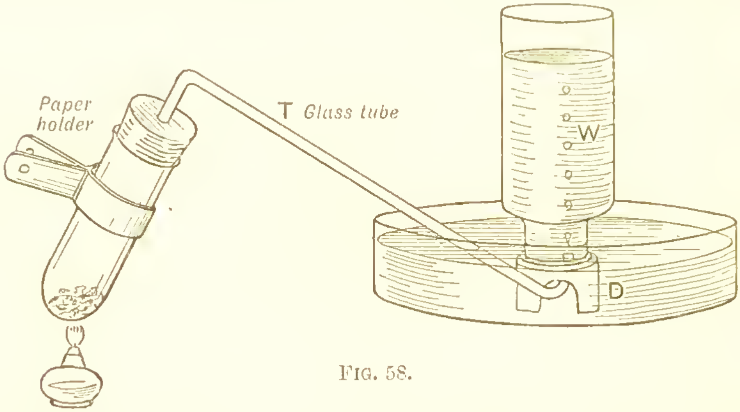


FIG. 58.

AIM.—To show that the change from purplish to scarlet blood is due to blood joining with oxygen of air, and to explain reverse colour change in tissues generally.

What are we going to try to discover to-day about blood? —Whether blood gets a brighter red if we put it in oxygen. Here I have a jar into which the butcher poured some blood for me. What has happened to the blood? (Pour off the yellowish serum and show the children the dark red clot left in the jar.) Part of it has gone solid, and I can pour off this yellowish-red liquid leaving a solid red *clot* in the centre. Blood always clots like this when it is shed. What good will that be to the body?—If the body is wounded, the clot that forms on its surface forms a plug to the vessels from which the blood is running, and after a time no more blood can run out. So when once a wound is washed clean and bound up, it is best to leave it alone to begin to heal. If it is disturbed too soon, the clots formed get pulled away, and the blood begins to run again. Nearly all the colour is in the clot, so we will use that. Here in this jar I have two pieces of a clot which I cut off the big clot, and put here in a jar of carbon dioxide gas. Why didn't I leave it in open air?—Oxygen in air might have already joined with it. Here I have a jar of pure oxygen. I take out one of the pieces of clot from the carbon dioxide gas jar, and drop it into the oxygen jar, and gently roll it about. After a few minutes pass the two jars round. The clot in the oxygen is much brighter red than that in the carbon dioxide gas. Cut away a piece of the large clot standing open to air. What difference is there between colour of inside and outside of clot?—Inside is much less bright red than outside. Why?—Oxygen of air can get at the outside. Now write a sentence to explain why the blood in lungs changes its colour from purplish to scarlet.

"Oxygen breathed into the thin-walled tubes of lungs passes through those and into the thin walls of the tiniest branch of the lung artery; joins with blood, and blood then becomes scarlet."

What then happens to the blood carrying the oxygen?—Goes out of the lungs in the fine branches of the *vein*, and these branches all collect up into big veins. Where do they go?—To the heart, the top left room. And where next?—Down into large bottom left room, and out by the big artery, still scarlet in colour, and away to the stomach and other parts of digestive tube, to the arms, to the legs, to the brain.

Do these parts of your body want oxygen? Suppose you want to move an arm. What must you have?—Energy. Suppose it is cold, will the protoplasm of cells in a finger go on working if they have no heat energy? Remember the yeast cells would not work well unless you put them in front of a fire, or warmed up in some way. So the cells everywhere want energy for warmth, and, if you are still young, for growth. Where does the energy come from ?—Oxidation of food. What brings the food to the cell protoplasm of the arm, leg, etc. ?—The blood. What else is wanted for oxidation besides cell protoplasm and food ?—Oxygen. What brings the oxygen ?—The blood. If the oxygen is used to oxidise the food to give the energy and heat, what will happen to the colour of the blood ?—It will go purplish-red again. And *where* will it go purplish red ?—In the arm, or leg, or brain, or digestive tube which is growing or working. And what will be formed in those parts of the body where food is being oxidised ?—Carbon dioxide gas and water. Do you think they will stop in the cells where they are made ?—No, they are mostly waste, and must be got rid of, the water passing through special passages, partly from the skin as perspiration, and partly through the lungs and windpipe when you breathe out. How do you get rid of the carbon dioxide gas ? How did you discover that foods were oxidised in the body ?—By breathing into lime-water (like this), and seeing that you breathe out carbon dioxide gas, for your breath turns lime-water milky. Where has that breath come from ?—Up the windpipe from the lungs. So that is where the carbon dioxide gas has come from. How did it get there from the arms, or leg, or brain where it was made ? You can't do an experiment which shows this, so I must tell you. The carbon dioxide gas is carried to the lungs by the blood. When the blood gives up oxygen it has the power to collect the waste carbon dioxide gas and carry it away. If it were not carried away the protoplasm would be poisoned by it, as it is by alcohol, and could not do its work of building up anew bone and muscle, or of oxidising the food, and so providing the energy for growth and movement. If protoplasm couldn't do this what would happen ?—It would die, *i.e.* your body would die. Equally, of course, the protoplasm would die if it had no oxygen or no food. Write down the three things which blood-stream does, without any one of which body would die.

It carries oxygen to protoplasm of every part of body ; it carries food to every part of body ; it carries carbon dioxide gas *from* every part of body.

SECTION XXXVII

Aim.—To show that the various functions of the blood are carried out by different constituents.

Requirements.—(1) Tie up small pieces of fresh blood clot in muslin, and by squeezing under water remove the red corpuscles; leave in muslin under a gentle stream of water till the fibrin is nearly colourless.

(2) After a fresh clot has stood for some two days, drain off the liquid which squeezes out of it, into a jar; if red, allow to stand till the red corpuscles sink to bottom, leaving the yellowish serum above.

(3) Have a live tadpole in a drop of water on a hollowed-out glass slide, covered with a thin glass cover slip, under low power of microscope. Model of red corpuscle. Fehling. Ammonia. Nitric acid. Diagram of capillaries in tadpole's tail.

(*N.B.*—Blood used and clots, etc., must all be kept *cool* and covered up, and won't "keep" at all well in hot weather.)

What are some of the foods that blood collects when it passes over the digestive-tube wall?—Sugars, fats, and digested nitrogen foods. Which kind of food is most like the substance which becomes solid and makes a clot when blood shed? Here is a piece of clot. How does it differ from the clot you saw last lesson?—It is practically colourless. I washed it well in water, and the red washed out. So the red part of blood is *not* the part that clots. How can we find out if nitrogen food was used to make the clot?

Heat a little bit in a small glass tube, and let the fumes come against damp pink litmus-paper. (Let two children come out and get this ready.) Which food-stuff does the colourless clot look and feel most like?—Sugary, fatty, or meaty foods. It is most like washed stringy muscle, or gluten of bread. What comes away when the clot is heated?—Ammonia. So it contains nitrogen. So clot substance is one other thing that is built up from nitrogen foods. Was there any part of the blood which did not clot?—The clot stood in liquid, and when it was left the clot got smaller, shrunk, and in shrinking squeezed out more of the liquid. I drained it off after two days, and here is some of it. (Test-tube or jar with yellowish serum above and red corpuscle layer below.) What has happened ?—All the red part has sunk to the bottom and there is a yellowish liquid on top. Would you expect to find any nitrogen food in this liquid ?– There must be some somewhere that the blood doesn't use itself, and which can be used by the other parts of the body. We will see if there is any in the clear liquid. Take a few c.c. and boil. Thick whitish solid appears. Is that solid like anything you have ever seen before ? What would happen if I mixed a little raw white of egg with water and boiled ?—We should get the same sort of

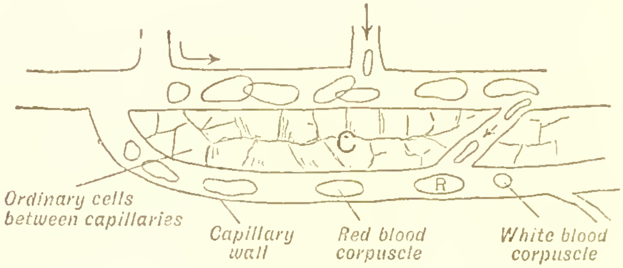


Fig. 59.

solid, and that solid, you know, we found was a nitrogen food. How can I prove that *this* white solid which comes when we boil clear liquid part of blood (serum) is nitrogen food ?—(Heat and test with litmus for ammonia, or add nitric acid, boil, cool, and add ammonia.) So we have shown presence of nitrogen food in the liquid part of blood. It is in this part, too, that the other foods are present. What will they be ?—Sugars, fats, salt, water. Let a child drop a drop of serum on white copper sulphate. What does it show ?—Water present. What part of blood have we still got to talk about ?—Red part. What does it do ?—Carries oxygen to, and waste carbon dioxide gas away from all parts of body.

The part of the blood that does this is alive, and here you can actually see the live carriers of oxygen in the blood.

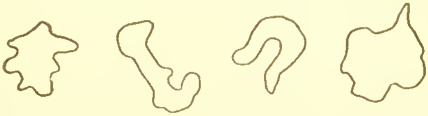
(Let children come out one by one to see tadpole's tail, while the rest draw diagram as drawn on board. If this is done, this lesson will end here. If impossible to arrange the tadpole under a microscope, put up diagram and discuss.)

If you could see the blood in the tiniest branches of one of your arteries you would see something like this.

[Names not to be written up for the children.]

C are cells containing protoplasm. They form the greater part of the tail, and running among them are the branching tubes through which the blood rushes, but it would not look just a red liquid, you would see a number of faintly reddish, oval-shaped bodies (like R) rushing along in a colourless liquid, sometimes squeezing round corners into the narrower tubes.

They are protoplasm or living substance, separate cells just as the yeast cell was, and are called red corpuscles (*cle*, little; *cp.* icicle). *Corpus*, you know, is corpse—body, so words mean red little bodies. They are little indeed. Here I have a gelatine model to show their shape. Oval, hollow one side. Model is an inch long. If I could put 3000 of the red corpuscles side by side they would just reach across it, so they are very small but there are as many as 5 millions of them in a drop of blood the size of a pin's head. Now why do you think blood is an all-red liquid?—Corpuscles are so closely packed that you can't possibly see the spaces in between when blood is shed, so you think it is red all through. If you look very carefully at the vessels you can sometimes see also some quite colourless round little bodies. What do you think they might be called?—"White corpuscles." They too are life substance, and *they* can change their shape, somtimes pushing out at one side, sometimes at another. How many have I put in the diagram?—Only three. They are much fewer than the red corpuscles—1 white, 500 red. Of course that means millions in the whole body.



Shapes of a single white corpuscle at different moments.

FIG. 60.

SECTION XXXVIII

AIMS.—To learn function of white blood corpuscles and the effect of alcohol on red and white corpuscles.

REQUIREMENTS.—Diagram of vessels in tadpole's tail. Diagram of tubercle bacilli.

Any children who have not seen it can see the blood-stream in tadpole's tail, while rest answer questions in writing.

What does the liquid part of the blood do for the body ?

What are red corpuscles, and what do they do for the body ?

When all have seen the tadpole's tail have some answers to the last question read out.

What do red corpuscles do for the body ?—Pick up the oxygen in the lungs and carry it to the parts of the body where energy is required. What happens ?—These red corpuscles give up the oxygen, and food is oxidised. As every movement needs oxygen, and heat is wanted everywhere, you can see why such billions of little oxygen carriers are wanted. And then these same red corpuscles pick up one of the waste substances formed when food oxidised. Which waste do they pick up ?—The carbon dioxide gas. (*N.B.*—Much of the carbon dioxide is removed as carbonate in the liquid part of the blood.) Where do they take it ?—To lungs. There they give it off ; and how is it got rid of from body ?—Breathed out.

What have we left for our white corpuscle to do ?

The liquid part of blood carries the food (the shopman) and the water (water company) ; the red corpuscles take the oxygen (gas company) and carry away the carbon dioxide gas (scavengers). Well, the white corpuscles you may say are some of the policemen of the body, they take up bad characters. Here is a bad character which sometimes gets into the blood. (Diagram of consumption or tubercle bacillus.)

Many illnesses, including diphtheria, scarlet fever, small-pox, are carried by bad characters like this. They are just single cells of living protoplasm, just as the yeast is, only a different shape and much, much smaller.

If they are allowed to wander about in the blood, these "bad characters" seem to upset all the workings of its protoplasm. Very often one sign of this is that more heat is produced than the body needs or can get rid of, the temperature rises, and we say the person is feverish. Can you tell me some diseases where this happens? If things get very bad, the protoplasm can work no longer and dies. What do we call these "bad characters" which cause diseases?—Germs, microbes. How does the white blood corpuscle deal with the bad characters, the germs?—It literally "takes them up." Here is a picture of a white corpuscle which has taken up some of the germs of consumption that were wandering in some person's blood.

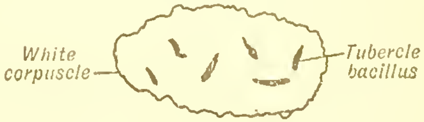


FIG. 61.

When the white corpuscle meets a germ it pushes out its protoplasm and flows round it like this. Once inside, the protoplasm of the corpuscle seems to act on the germ somewhat as the ferments act on foods. How is that?—Dissolves it up, breaking up the protoplasm of the germ into other things, so that it can no longer do any harm. When disease germs enter the blood then, in the food or water, or from the air, the corpuscles hurry up to the attack. If there are plenty of healthy corpuscles what will happen?—All the germs will be swallowed up and destroyed and no harm done. If the corpuscles are few and weak, the germs win, and the person in whose blood the battle takes place will be very ill and may die. Now answer for me to put on board, "What are the different parts of the blood, and what do each do for the body?"

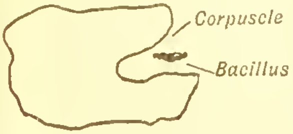


FIG. 62.

On Board

1. A substance which can clot and prevent bleeding at wounds.
2. Liquid part carrying water and dissolved sugary, fatty, and nitrogen foods.
3. Red corpuscles, carriers of oxygen and carbon dioxide gas.
4. White corpuscles, destroyers of germs.

What happens to all these important parts of the blood if alcohol in ale or spirits or other drinks is swallowed? Can the alcohol get into the blood?—Yes, very quickly, two minutes after taking it some of it has passed through the walls of digestive tube into the tiny branches of the blood-vessels which cover it.

Which part of the blood will you expect alcohol to especially attack? Living parts or the food materials?—Living parts. It hurts yeast cells and the seeds or eggs of all living things. Which parts of blood are very like those?—Red and white corpuscles, for both are living protoplasm. Scientists have found that quite small quantities of alcohol damage the protoplasm of red corpuscles, and make them more liable to be dissolved and broken up. If you have fewer red blood corpuscles you may look pale, and people often then say you are anaemic. Anaemia may be brought about by bad or too little food, or because food is not properly digested, and in other ways, and one of these other ways is by taking alcohol. Why does it matter to the body if its red corpuscles are destroyed or unhealthy?—Oxygen is not properly carried to different parts of the body or carbon dioxide gas away. Where is oxygen wanted?—Where building up of new muscle or bone is going on, or where there is movement. So will children or grown-ups need most oxygen?—Children; their protoplasm has far more of this work to do. So children want heaps of healthy red corpuscles and certainly don't want alcohol to make those useful little bodies weak. Will alcohol do anything to the "policemen" of the body?—Yes, they are alive too, and the alcohol just paralyses them; very tiny quantities of drink makes the white blood corpuscles still and useless in the presence of dangerous germs, which, if they were healthy, they would swallow up and destroy. When the germs of some disease get into a person who drinks beer or spirits, they are not destroyed readily by his white blood corpuscles, as they would be by those of a teetotaller. If the germs are not destroyed what happens?—The person gets the illness, diphtheria, or typhoid, or consumption, which is given by that germ. With some skin diseases the white blood corpuscle never is able to drive out the germ from people who take much alcoholic drink, and so it is found that brewers and their draymen suffer especially from those diseases. Where does the alcohol go, once it is in the blood ?—All over the body. Will it find anything to hurt outside the blood-vessels when it passes through their walls ?—Yes, everywhere there is protoplasm, and it must affect the protoplasm, the living substance, and make it less able to do its work and more ready to be attacked by any disease germ.

Write down the three important parts of the body which in this lesson I have told you are hurt by alcohol.

(*Note.*—Children may ask why people who drink have red faces, whereas one would expect them to be anaemic. See Section XLI. for the action of alcohol in distending blood-vessels, to explain this. It is the excess of blood present in the permanently distended capillaries which causes the unpleasant redness, not an increased number of red corpuscles in the blood.)

SECTION XXXIX

Aim.—To learn the effects of alcohol on red blood corpuscles and muscle of heart itself.

How is a red blood corpuscle like a yeast cell ?—It is a tiny mass of protoplasm or life substance. What can all such protoplasm do ?—Take up dissolved food materials. What is the food used for ?—To build up new life substance and for energy. What good is that ?—The protoplasm grows, is kept properly warm, and is able to do work and cause movements. (*N.B.*—A red corpuscle grows to a certain size, but does not bud out like a yeast cell, or divide like a frog's egg when it is worn out ; it is apparently destroyed in the liver, while new corpuscles are made in the *red* marrow of bones.) What work do the red " little bodies " (red corpuscles) do ?—They carry oxygen to all parts of the body and bring away waste carbon dioxide gas. What substance was it which stopped yeast and frog's eggs from growing, which was *their* work ?—Alcohol. Would you expect alcohol to stop red corpuscles from working ? —Yes. Why ?—Because they, too, are made of protoplasm, just like the yeast and the frog's eggs.

Scientific men have made many experiments and found that a small quantity of alcohol taken often, *e.g.* every day, does hurt the red corpuscles just as you would think, and so prevents them from doing their work. If the body does not get its proper amount of oxygen what will happen ?—Food will not be oxidised. Why does that matter ?—The heat of the body won't be kept up, and also the body has no energy for movement or such work as thinking. Have you ever seen any one whose red corpuscles were not healthy and doing their work properly ? What colour would you expect them to be ?—Pale. " Anaemic " we say. Are those people lively, energetic, clever ?—No. They want to sit still. They can't think quickly, are not sharp, often feel cold. Why ?—Their red corpuscles are few or unhealthy, not carrying oxygen over the body, the food not being oxidised properly to give the energy the body needs. Several things, bad food, or too little food, or not enough sleep, may make their red corpuscles weak and lazy in this way. What other thing have we also said does this ?—Alcohol. So would you give a pale anaemic person stout, or winearnis, or any such patent wine ?—No. Why ?—Because it contains alcohol, which only further weakens the protoplasm of the corpuscles. What would you give them ?—Milk and really nourishing foods which can be used by the protoplasm to build up new healthy corpuscles. Two children come out and write up on blackboard on one side some things that hurt red corpuscles, on the other some things that help make strong red corpuscles. (Sleep, fresh air, good food, good drinks, exercise.)

Is there anything else in the blood rather like the red blood corpuscles ?—The white corpuscles. What does alcohol do to them ?—Paralyses them so that they can't destroy, swallow up, germs. How does a drinker differ there from a teetotaller ? —People who take alcohol catch illnesses like diphtheria and typhoid much more easily, and have them worse than teetotallers. How does alcohol get into the blood to do all this mischief ?—People drink it in ale or spirits, or in some patent medicines. Where does it go ?—Into digestive tube first. Can it get through the wall ?—Yes, very quickly, quicker than almost anything else we eat or drink. What does it pass into ? —The fine branches of the blood-vessels. Where is it carried at once ?—To the heart and to all parts of the body, everywhere hurting corpuscles as it goes. Can alcohol hurt the heart itself ? What is the heart mostly made of ?—Muscle. What is this muscle doing all your life ?—Shortening and lengthening so that the rooms in the heart get smaller and bigger, and the blood is pumped in and out.

(Heart muscle automatically contracts; it is not under control of the brain or grey matter of spinal cord in the same way as the rest of body muscles are, though contraction is regulated, *i.e. quickened* or *slowed*, by messages from central nervous system.) Many scientific men have tried the effect of alcohol on this heart muscle, and they find that when there is only ·5 per cent in the blood the muscle slowly weakens and does not work properly. (Let a girl measure into a glass 99½ teaspoonfuls of water and colour it with red ink.) Why does it matter if heart muscle no longer shortens and lengthens as it ought ?—Blood is not pumped in and out of the heart and all over the body as it should be. What does that prevent the protoplasm from getting ?—Some of the food and oxygen it needs. Here are 100 teaspoonfuls of red water. Suppose it is blood in a blood-vessel. How much alcohol must I add to make it of ·5 per cent strength ?—Only ½ a teaspoonful. A glass or two of ale would soon send as much alcohol as this into the blood-stream. Of course, the bad effect on the heart muscle of a very little alcohol is not very great at first, but if day after day the dose of alcohol is repeated, it means that the heart muscle itself doesn't have as much blood pumped through it as it wants. Why does heart muscle especially require lots of blood ?—It is always working and always wanting more food to build up new muscle, protoplasm, and to supply energy. What will happen if the blood supply to it is less ?—Can't work so well, so shortens and lengthens less and less well as the months go on when alcohol is being taken. Many people who have taken a little alcohol daily for years, when they leave it off, find they have far more energy after some weeks as teetotallers, because their heart muscle recovers and now pumps the blood with its food and oxygen properly to all parts of the body.

(Here should come the contents of Section II. (*c*), Board of Education Temperance Syllabus.)

Answer in writing :

1. What does the blood carry to the life substance in all parts of the body ?
2. What is it makes blood move all over the body ?
3. What does alcohol do to heart muscle ?
4. How much alcohol will do this ?
5. Why would you expect a teetotaller to be :
   (*a*) More energetic than a drinker of alcohol ?
   (*b*) Less likely to catch fevers ?

((*a*) should be of course a summary of the answers to 1, 2, 3, and 4.)

SECTION XL

Aim.—To grasp the idea of the nervous system as the controlling factor in physical life and deadly effect of alcohol upon it.

I want to write upon board a list of the parts of the body we have talked about and what they are used for. (Possible questions.)

What happens to the food we eat ?

Where does digested food go from digestive tube ?

What pumps the blood round the body ?

What is food used for by protoplasm ?

Where does oxygen come from ?

What happens to the waste carbon dioxide gas ?

How do different parts of the body move ?

(From these and similar questions get the following on board :)

Digestive Tube.—Food is made soluble so that it can pass through the digestive tube and blood-vessel wall, so that the protoplasm can use it.

Blood-Vessels and Heart.—Pump the blood into any part of the body.

Arteries.—Take the blood *from* the heart.

1. Blood with oxygen to protoplasm everywhere.
2. Blood with waste carbon dioxide gas to the lungs.

Veins.—Take blood *to* the heart.

1. From the body, carrying waste carbon dioxide gas.
2. From the lungs carrying oxygen.

Hair-like thin-walled tubes joining veins and arteries.

Through their thin walls food, oxygen, carbon dioxide gas, and water pass.

Lungs.—The place where the blood can give up its carbon dioxide gas and get fresh supplies of oxygen.

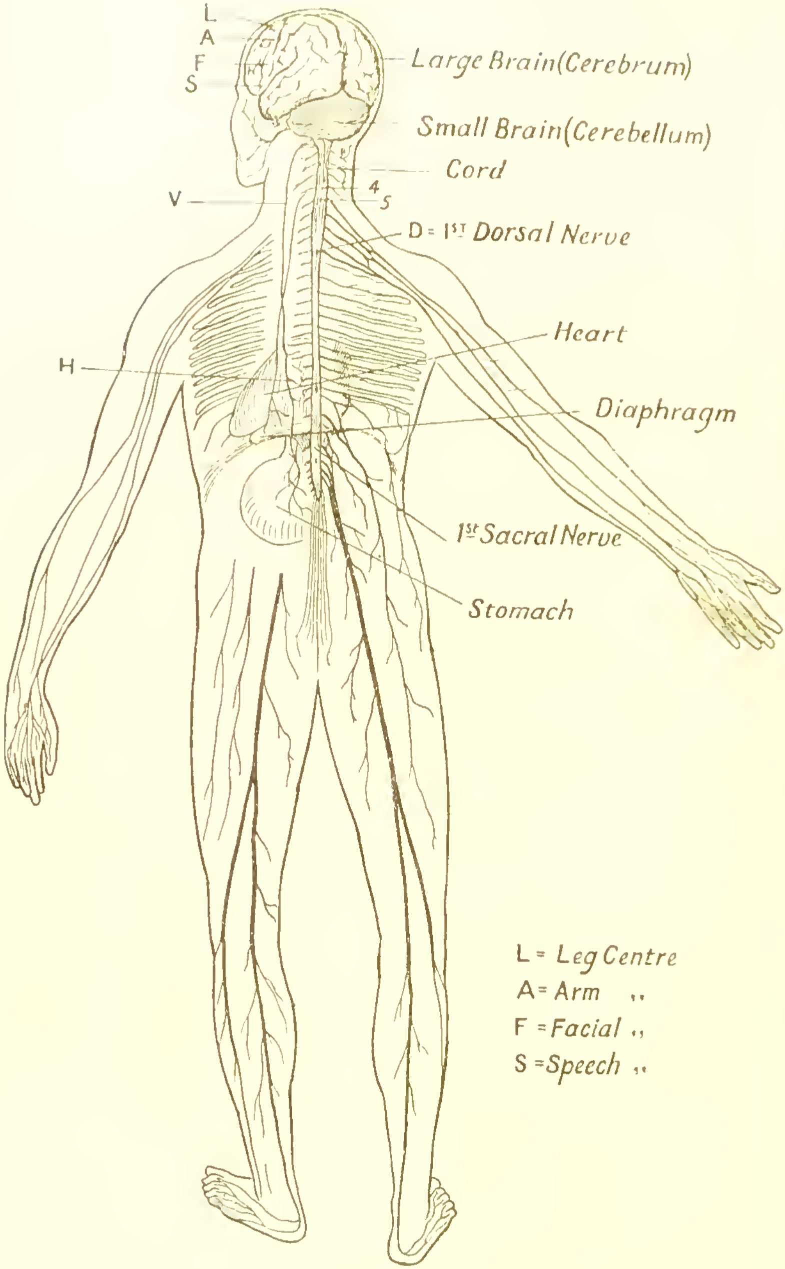


FIG. 63.—Nervous system, including vagus or tenth nerve going to the stomach and giving a branch to the heart.

Muscle.—All the movements in the body, *e.g.* of limbs, digestive tube, or heart, are brought about by shortening and lengthening of muscle.

What is it that you would find everywhere in the body, doing all the work, *e.g.* in the wall of the digestive tube making the juices that are to digest the food ?—Protoplasm. In blood carrying the oxygen and carbon dioxide gas ?—The protoplasm of the red corpuscles. In muscle bringing about its shortening and lengthening and building up new muscle as the old is worn out ?—Again protoplasm. But does the protoplasm in any one part of the body work all "on its own," and is there no special protoplasm which has charge of all the rest, and can stop its work or quicken it for a time if necessary ? What is it that tells the protoplasm of muscles in the hand that they have to shorten so that hand can pick up a fork ? What did we find in the leg of the rabbit ?—Long white nerves which led from the brain or cord to muscle. The protoplasm of the brain sent a message down the protoplasm in a nerve to the muscle protoplasm and the muscle substance shortened and then lengthened again. The same sort of thing happens everywhere, the protoplasm in the brain or in the long continuation of the brain, which runs down inside the backbone and which we call the cord, continually sends out messages to the protoplasm everywhere in the body, starting it at work or stopping it, or hurrying it up or slowing it. Here is a picture of the brain and its continuation the spinal cord, with the protecting backbone taken away ; and here you see the "nerves," as we call them, going off to different parts of the body. Where will many of these nerves be going to ?—Muscles of limbs. But here is one that is going somewhere else. Where ?—To the digestive tube. What messages might its protoplasm take ?—A message to the muscles of the wall to shorten so that food may be churned up, or a message to the protoplasm in the wall to make ferments and juices for digestion of the food.

(Stimulation of vagus nerve changes the rate and amount of contraction of muscular walls of digestive tube, also secretion of gastric juice. If the splanchnic nerve, *i.e.* a nerve from the sympathetic system, is stimulated, this causes contraction of artery muscles, thereby causing diminished blood supply, and therefore diminished activity of stomach muscles.) Here is another nerve going to the heart (another branch of vagus).

We said heart muscle can shorten and lengthen without messages from the commanding brain and nerve protoplasm, but sometimes it does this too quickly and the heart "beats" too fast, then along comes a message by this nerve to slow down to the proper pace. What other way might the heart muscle work wrongly ?—It might shorten too slowly, not enough in a minute; then down another nerve would come a message to quicken up.

Then there are some nerves that take messages *to* the brain protoplasm or its continuation inside the backbone. I will show you this happening. (Have a child come out in front of the class.) Now all of you watch carefully what happens. (Don't touch the child, but bring your hand down as near the eye as possible without touching.) What happened ?—She blinked. Why did she blink ?—A nerve running from the eye to some protoplasm in the cord took a message that something was coming which would hurt the eye, and before the hand could get there, more nerves brought back messages to the muscle moving the eyelid commanding them to shorten and so close the eyelid. Can you think of any other times when messages of danger are taken like this to the central commanding brain or to the cord protoplasm and messages are sent back to muscles to avoid danger ? (Touching something very hot, *e.g.* in sole of foot, muscles not actually *touching* the hot thing are made to remove the foot. Swallow a crumb "wrong way," some muscles of windpipe get message to contract, and a cough is the result to expel the crumb.)

Again what happens when you see a sweet and pick it up to eat it ? What takes the message to the brain protoplasm that the sweet is there ?—A nerve from the eye, then a certain part of the brain protoplasm "thinks" about it, as we say, and sends a message to the muscles of the hand and arm to shorten and lengthen in such a way that the hand can pick it up ? What takes *that* message ?—Nerves again. Meanwhile, perhaps, your mouth "waters." Why is that ?—The brain has sent another message to the protoplasm in that part of the mouth which makes saliva to make haste and make the saliva to begin to digest a nice sweet that is coming to it. Probably even some messages have gone to the digestive tube to get the protoplasm in its walls to make *its* digestive juices all ready, and all these messages have gone by means of the protoplasm of the nerves, and all so quickly that you would not say you had thought about eating that sweet at all. Each of you draw a sweet, an eye, dot for brain protoplasm, a hand, and put in lines to show how a message goes. When you don't have to *think* about an action at all, *e.g.* to pull hand away from a too hot flat iron, it only takes about *three-fiftieths* of a second for message to go to the cord by one nerve and from cord by another nerve to the muscles, which will at once contract and move the hand away. Suppose it is a case of thinking, *e.g.* seeing a sweet, thinking you want to eat it, and the message to come from *brain* to arm and hand muscles to shorten, then, in order to do this, it takes a bit longer, perhaps *one-fiftieth* of a second. If you want to be quick in getting yourself out of danger what, above all, must you keep healthy ?—Protoplasm of brain, cord, and nerves. If you want to think quickly and well, what must be healthy ?—Brain protoplasm. If you want to move quickly and deftly you must have the brain protoplasm and nerve protoplasm able to give its commands rightly to the muscles. If your digestion is to go on properly, what must be in order ?—Nerves which take messages to digestive muscles and to protoplasm which builds up digestive juices and the protoplasm of brain from which those messages come. If your heart muscle is to be guided and controlled so that heart beats in the right way, neither too slow nor too great, what must be healthy ? Some child come out and point out parts on diagram, brain protoplasm and nerve to heart. Why is it that a drunken man cannot walk straight ?—Alcohol has poisoned the protoplasm of a part of brain (cerebellum) which sends messages to muscles when a good many are required to act all at once to make a movement. Since this protoplasm is poisoned the muscles do not get the right messages, some perhaps get none at all, and so the right movements are not made. Through this accidents often happen. Give me some examples of accidents due to muscles not working properly. A doctor found that in Edinburgh some years ago, when public-houses were open on Saturday night, the number of accidents was double those which occurred on any other day. Why, do you think ?—Men were paid their wages and drank beer and spirits. What did the alcohol do to them ?—It affected the protoplasm of their brains, and they didn't see dangers quickly, *i.e.* the messages brought by the nerves from the outside world to the brain inside were not understood, or the messages sent to the muscles were slow or muddled, wrong movements were made, and an accident happened. But does a *little* alcohol hurt the protoplasm of brain, cord, and nerve? I want you all to do an experiment, and then you will be able to understand how scientific men tried if alcohol in small doses would hurt the brain protoplasm. When I tap on this table with this ruler I want each of you to put your right hand up. Now! Yes, you all did that pretty quickly, some were quicker than others. Why?—Probably brain protoplasm in a healthier condition sent a message quicker down the nerves to the arm muscles. Those people, perhaps, are getting more sleep or better food than the slow ones. When brain protoplasm is growing you need lots of sleep. What do you think would happen if I gave each of you a very little alcohol ($\frac{1}{4}$ oz.)? (Show 8 oz. medicine bottle with $\frac{1}{4}$ oz. marked.) Just for the first 10 minutes you might be quicker in putting your hands up when I tap, but after that you would be slower and slower, and would stay slow for 4 or 5 hours as long as any alcohol remained in the body. Why?—Because alcohol poisons the brain protoplasm and the messages are slowed. Now here is another experiment. Add up the sums on board and put your hand up the second you finish them all, *e.g.* 2+3, 7+2, 8+9, 23+16? Which do you "think" about most, adding up such sums or putting up a hand at a tap? Which is the most important, to think well or make such a movement quickly?—To think well. It is most important that that part of the protoplasm of the brain which does such thinking should be healthy and able to think well and quickly. If you added up figures every day for six days, would you do it better than at first?—Yes, brain protoplasm would have "got the habit." Well, some men did this and got quite quick, and then on the seventh day they took a little alcohol and went on taking some each day. What do you think happened?—They at once got slower and they made more mistakes. Why?—Because alcohol had poisoned that part of the brain which does the thinking. What part of your body do you remember with?—Protoplasm of brain. What will you expect to happen to a brain which has been poisoned by alcohol?—Memory gets bad, can't trust what such folk say, often because they don't remember what really happened. When you *will* to do something, say to drink one thing and not another, what part of your body is used in the willing, the deciding what you will do, and doing it ?—Protoplasm of brain. It has to think about all the reasons for drinking the one thing and not the other. Give me some reasons. Such reasons as, What is that drink made of ? Will anything in it hurt my body ? Does it matter if any part of my body is hurt ? Will it affect my work ? What work am I going to do ? Will that work hurt or help the other people I work with or for ? Shall I get on in the world if I can't do my work properly ? and so on ; heaps of things the brain protoplasm has to think out. Suppose you have been drinking alcohol, even a little. Will your brain protoplasm be as able to think clearly and quickly as the man who has never taken any alcohol ? So the teetotaller is likely to remain a teetotaller because he can think more clearly about these things. Will it ever matter to other people if you take alcohol and your muscles don't get the right messages in good time from the brain or cord ? Suppose you are driving a taxi and an hour before you started you took some drink, some one darts across in front of your cab, will your brain send a message to your hand and arm muscle to turn the wheel so quickly as it would have done if you had had no alcohol ?—Almost certainly it won't, and by that small amount of difference you may have an accident and run over the person. (Signalmen, machinists of all kinds, commanders of ships or armies all need to decide quickly and accurately.) How long do you think your brain protoplasm goes on growing ?—Till you are thirty, and the younger you are the less grown it is and the more delicate and more easily injured. Once the brain protoplasm is injured it is the most difficult of any part of the body to repair, and, as we have seen, it is by far the most important. You saw what alcohol did to young growing protoplasm in frogs' eggs and yeast. It is just as bad for growing brain protoplasm. Children who want in the future to think well, to remember well, to move well, *i.e.* do things through their muscles deftly and not clumsily (here put in any trades the children know), must not drink alcohol. Why not ?—Alcohol hurts protoplasm of the brain and cord which controls all these things.

SECTION XLI

Aim.—To give some common examples of the way in which alcohol deceives people.

Give me the reason why alcohol, even in small quantities, makes people forgetful, even untruthful, less able to do good head work, such as sums or clerks' work, clumsier, less able to save themselves from accidents, and in fact much less useful in the world than they might be. Alcohol hurts the delicate protoplasm of brain and cord which rules all the other protoplasm in the body. Why then are there so many public-houses and so many people who take alcohol ? Many of those who drink never heard the reasons for *not* taking alcohol as you have learnt them. They think if they take " too much " it may be bad for them at the time, yet next day they suppose they will be all right again. They don't know that once they have hurt their delicate brain protoplasm it may take a long time to get right again ; they don't know that a teaspoonful of spirit, though it doesn't seem to hurt them, really makes the brain protoplasm less able to work well. They don't know that taken to-day, its hurting power lasts till to-morrow. Here is a true story which shows how alcohol takes a man's power of understanding away.

There were a number of men (compositors) who set up type for printing. Is that work which wants thinking about ?—Yes, wants an active brain and quick muscle action. Well, these men one day " set up " letters when they had had no drink, and the next day did same taking a *little* alcohol. It was found that they set up fewer letters on the days when they had drink. Why ?—The alcohol had hurt the brain protoplasm and thought, and the messages to the muscles went on slower. But the funny thing was that the men were quite sure that they were doing *better* work on the days they were taking alcohol, until the end of the day came and they counted up their letters, and found that they were working really badly. Why were they so mistaken in their judgment ? Again alcohol had poisoned brain protoplasm, and it could not think and understand properly. Alcohol then not only makes people work badly, but deceives them into thinking that they are working well so that they don't want to do better. But alcohol deceives people in other ways too. Have you ever heard a man or woman say " I'll take a drink to warm myself " ? Most people are quite sure about it, and yet, really, drinking makes a person colder in the end. *You* can understand how, now, because we have been learning how the body works. To explain it you must answer some questions.

Are you hotter inside your body or at the surface, which of course is the skin ?—We are hotter in the inner layers, and, for instance, where the heart is. Why ?—1. Chemical changes, oxidation which chiefly gives the heat, go on largely in deeper muscular layers. 2. The heat at surface is lost. How ?—It gives out to the surrounding cooler air, furniture, etc. How is the heat brought to the surface ? What is it that passes from inside to the outer layers of body ?—The blood-stream. Many blood-vessels, just under skin, bring hot blood to surface, What happens there ?—It loses some of its heat and goes back cooler to the heart and the inner parts of body. Can you ever get more blood suddenly brought to surface ? What happens when you blush ?—Much more blood is suddenly rushing through blood-vessels under skin. What must happen to wall of vessels if more blood can come into them, because the vessels are quite full to start with ?—The walls of the blood-vessel must stretch. Now the walls contain muscle fibres which are elastic, passing round them as this bit of red cotton is wound round this indiarubber tube. What could make the blood-vessel widen ?—If the muscle lengthened. What do you think could bring word to the muscle to lengthen ?—Nerve from brain or cord protoplasm, and that is what happens when a part works hard and wants more blood passing through it to bring oxygen or carry off carbon dioxide gas. A message comes along the nerve, the muscles round vessels then lengthen, and more blood can rush through. Alcohol, when it is carried in the blood to protoplasm of brain or cord, paralyses these controlling organs so that the muscles round blood-vessels lengthen, and the blood rushes more quickly to surface. When it first reaches the skin, what will skin feel like?—Warmer. So a message goes along a nerve from the skin to the brain protoplasm that it's warm, and the man thinks he is warmer all through. But what is the blood like as it goes back again inside body?—Cooler. So, after a time instead of being warmer, the whole body will be colder, because the hot blood has been bringing heat from inside and losing it at surface. Do Arctic explorers drink alcohol?—No; they know it really would make them colder, though for the first few minutes they would *feel* warmer. A drunken man sleeping out in cold will die, because the alcohol causes the blood to bring all the heat to the surface and lose it there. So you can tell any one who drinks to get warm that the alcohol is just deceiving them as usual. There is another time when people take alcohol because they don't know what it does to the body really. "I feel faint," says a woman, "I will have a drop to hearten me up." Why does any one "feel faint"?—The protoplasm of the brain is not working properly, the person can't think, and also messages are not being regularly sent out to the muscles of the limbs, to the heart, and all the other parts of the body. Can we think of anything that might have hurt the brain protoplasm and stopped its working? What is needed for any protoplasm to be built up and kept working?—Food and oxygen. What brings these to the brain?—Blood-stream. What sends the blood-stream up to the brain?—The pumping of the heart muscle. What then might be cause of "faintness," *i.e.* brain protoplasm working badly?—The heart muscle shortening and lengthening badly, and so too little blood passing through brain. What else might cause faintness?—Not enough food, or not enough oxygen in blood. Suppose it's any of these three. Can taking a drop of alcohol be good for the brain protoplasm, or give it the food or oxygen it needs?—No; when it reaches the protoplasm it will only weaken it still further and so make the heart beat even more feebly. Is alcohol itself a food?—No; as we saw, it has no building-up food in it. But still people always think it is good for faintness, because when it is given to a fainting person they revive. But if you made them sip hot milk, or bovril, or hot water, or even water, this would make the heart beat more quickly, and send the needed blood to the brain protoplasm. Is it better to give hot milk to a fainting or tired person rather than alcohol? We will put down what each does in two columns, then you can answer questions.

Alcohol Sipped.	*Hot Milk Sipped.*
(1) Action of sipping makes heart beat more quickly and so sends blood to brain.	Ditto. All that is usually needed to revive a fainting person.
(2) When it touches the nerves in the mouth and stomach it sends message to the brain protoplasm which for the minute causes the heart to work more quickly.	Ditto.
(3) Soon causes slowing of heart's action.	It nourishes heart and so keeps up right action.
(4) Hurts the brain protoplasm itself, making it sleepy and less active.	
(5) Does not help to build up or repair brain protoplasm.	Contains all the food materials necessary for activity and repair of brain protoplasm.

You might compare the tired brain protoplasm to a tired horse; both need food and rest. Suppose you whip the horse he will go a bit faster, but will only use up more of his protoplasm and muscle, and get more and more tired; or you may give him food and a rest, and his protoplasm will build itself up and he will be able to go on again. Is alcohol like the whip, or like the food and rest?—Like the whip. Which is milk like? Which would you rather give the brain protoplasm of a fainting or tired person, the whip, or the food and the rest?

We have had three ways in which alcohol deceives people; each of you write them down. 1. Makes them think they are doing better work when they are doing worse. 2. Makes them think they are getting more heat into their bodies when they are losing it from the skin. 3. Makes them think it is building up brain and other parts of body, and making them less tired and faint, when it's only acting like a whip to a tired horse, and they will be more tired than ever later on.

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